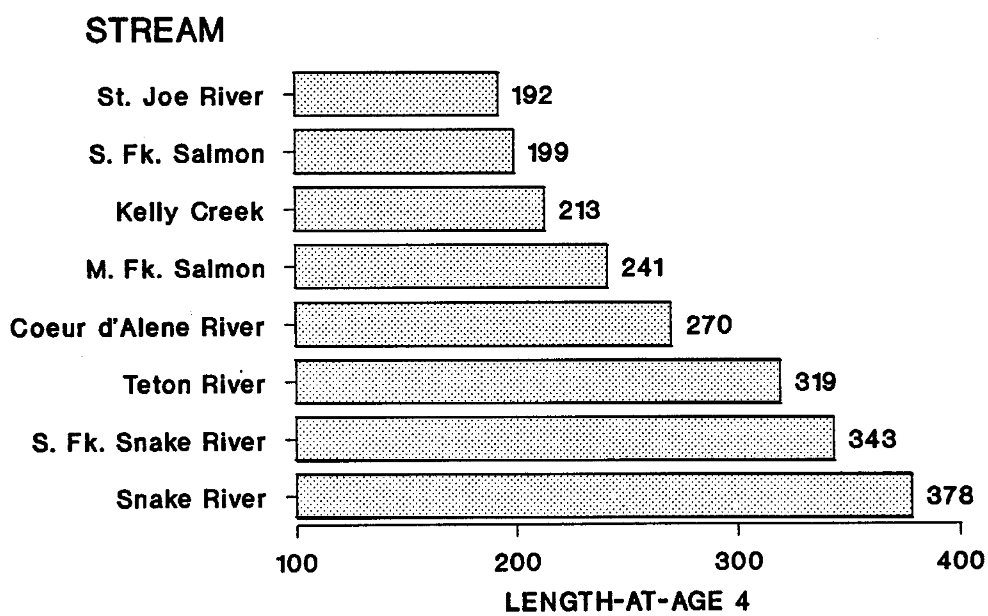
Volume 083 Article 05

FISHERY RESEARCH

JOB PERFORMANCE REPORT
Project F-73-R-13

Subproject II: River and Stream Investigations
Study IV: Wild Trout Investigations
Job 1: Statewide Data Summary
Job 2: Bull Trout Aging and Enumeration
Job 3: Bait Hooking Mortality Job 4:
Electrophoresls Sampling



By

Daniel J. Schill
Senior Fishery Research Biologist

September 1991

TABLE OF CONTENTS

Page

Job No. 1. Wild Trout Investigations: _ Statewide Data Summary, Statewide Population Simulations

LIST OF TABLES

Page

LIST OF FIGURES

LIST OF FIGURES (Cont.)

LIST OF APPENDICES

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CONTENTS

LIST OF FIGURES (Cont.)

LIST OF APPENDICES

Job No. 3. Hagerman Bait-Hooking Study

CONTENTS

TABLE OF CONTENTS (Cont.)

Page

LIST OF TABLES

LIST OF FIGURES

LIST OF FIGURES (Cont.)

LIST OF APPENDICES

Job No. 4. __Electrophoresis Sampling Guidelines

CONTENTS

JOB PERFORMANCE REPORT

State of: Idaho

Name: River and Stream Investigations

Project No.: F-73-R-13

Title: Wild Trout Investigations: Statewide Data Summary, Statewide Population Simulations

Subproject No.: II

Study No.: IV Job No.: 1

Period covered: March 1, 1990 to March 31, 1991

ABSTRACT

We summarized existing fishery and population data for a variety of Idaho wild trout fisheries. Growth of cutthroat trout *Oncorynchus clarki* was positively related to conductivity in Idaho waters ($p < .001$). We found no relationship for rainbow trout *Oncorhynchus mykiss*. Stream width explained a large part of the variation in trout density and growth. Statewide comparisons of angler effort and trout density were limited by a lack of surface area measurements for most streams. Season-long effort ranged from 70 to 1,100 h/hectare for waters with usable data. Wild trout harvest rates ranged from 0.05 to 0.43 fish/h, but were often near 0.25 fish/h. The development of a standardized sampling manual should be a priority in the future.

We used simulations to describe the potential stock structure of unexploited populations over a range of Idaho growth. Results suggest few streams in Idaho have the potential to be designated as trophy streams based on guidelines from the Idaho Department of Fish and Game Five-Year Management Plan. Simulated populations did not produce a population with 20% of fish exceeding 406 mm until length at age 4 approached 400 mm. Empirical validation is difficult because of sampling bias. Variable recruitment makes observed stock structures misleading or variable.

We simulated the effect of 12 regulations over a range of Idaho growth rates. Low exploitation rates (20%) had little effect on total numbers of catchable-sized fish greater than 153 mm or on egg production, regardless of regulation. Low exploitation had a substantial effect on numbers of quality-sized fish for all but the most restrictive regulations. Results show that, for biological purposes, the variety of regulations used on a statewide basis can be reduced.

Author:

Dan Schill
Senior Fishery Research Biologist

90REPRT

INTRODUCTION

The status of Idaho wild trout fisheries has been a focus of attention for Idaho fishery personnel for many years. Examples of successes include the South Fork Boise River, St. Joe River, Kelly Creek, the Henrys Fork of the Snake River, and the South Fork of the Snake River. Waters where special regulations have not produced expected results include the Coeur d'Alene and Blackfoot rivers.

Despite the time invested in wild trout management, Idaho still does not have a statewide perspective. Information tends to be drainage basin in nature or limited to geographic boundaries, such as northern Idaho or southeastern Idaho. The lack of broader perspective limits our ability to develop realistic management goals based on the previous experience of others. For example, density data from an individual water could be compared with a statewide data summary to see if room for improvement exists. If densities were on the lower end of the spectrum, improvements in the fishery would seem probable by some management action. If densities are high compared to the summary, new actions could be expected to have less or minimal effects.

The justification for this work is to increase our perspective to aid in better management decisions without the collection of additional data.

In presenting regulation alternatives to the public, perhaps the most often asked questions are: "How big will the fish be?" "How many more fish will there be?" Catch rates are important (Reid 1989), but anglers seem especially sensitive to changes in fish size (Parkinson et al. 1988). Thus, predictions of stock structure for catchable-sized segments of the population are important to anglers and managers.

The current Idaho Department of Fish and Game (IDFG) Five-Year Management Plan (Idaho Department of Fish and Game 1991) calls for designation of special regulation trout streams in Idaho as either quality or trophy, depending on the percentage of the population in excess of 16 inches. A knowledge of potential stock structures of our populations would help assess this standard. It would also help biologists and anglers develop realistic expectations on waters where regulation changes are being considered.

OBJECTIVES

1. To summarize existing population and fishery data on fluvial populations of wild trout in Idaho. Use this data to develop empirical predictive models for Idaho waters.

2. To develop possible size structure goals for wild trout populations in Idaho.

3. To examine regulation alternatives on a statewide basis and evaluate the number needed to meet management goals in terms of fish numbers, size, and recruitment.

METHODS

Statewide Data Summary

The approach was to summarize existing data describing wild trout populations and their management in Idaho. We focused on data collected during the last decade. Data were obtained through agency and university reports. No attempt was made to examine raw data in files. Species included in the summary were cutthroat, rainbow, brown, bull, and brook trout. The variables selected for comparison were:

Population Data

Growth- Expressed as back-calculated length at age 4. Summarized for stream stocks only.

Densities- Expressed as numbers of age 1+ fish/hectare and age 1+ fish/stream km.

Estimates were determined by electrofishing or snorkeling techniques. Mean densities (total for all species) are reported for individual streams, along with the range observed among sampling stations. If sampling was done several times throughout the season, we averaged all estimates for a grand mean for each site. In some cases, only a single site was sampled. Fry were excluded from the database because of their misleading effect on overall density (Platts and McHenry 1988). We did not include adfluvial stocks in the summary since large segments of these populations would be missing for comparisons.

Stock Structure- Expressed as the percent of fish larger than 305, 406, and 508 mm. The above indices were applied only to those fish exceeding 200 mm in total length (see Anderson 1980). In subsequent discussions, we refer to the 305, 406, and 508 mm percentages as proportional stock structure (PSD), quality stock structure (QSD), and trophy stock structure (TSD), respectively (Idaho Department of Fish and Game 1991). We calculated stock structures for individual streams. When multiple stations and seasonal samples were available, we calculated weighted averages based on fish numbers. In some cases, we approximated values from graphical length frequencies when numerical data were not provided in the report.

Standing Crop- Expressed as kg/hectare.

Natural Mortality- Expressed as conditional annual rate (Ricker 1975).

Fishery Data

Fishery parameters were summarized from formal creel surveys. We used only data that covered most of the angling season (typically late May to September, October, or November) and considered them as approximations of season totals. A list of actual census dates is available in Appendix A.

We summarized the following:

Angler Effort- Expressed as angler h/hectare and h/km. Harvest (Number/km and number/hectare), Yield (Kg/hectare), Mean length harvest (mm), Mean weight of individual fish in the harvest (g), Stock structure (Proportion in the 200 mm+ harvest that exceeded 305, 405, and 508 mm), Catch rate (Fish/h), and Harvest rate (Fish/h).

Physical Habitat Data

We summarized conductivity and stream width to describe relationships with the biological and fishery variables. Late summer to fall conductivities were obtained from data in individual reports and, in some cases, from project sampling. Stream width data was derived from information in reports and from IDFG Regional Management files. We used simple linear regression analysis to examine relationships between growth (length at age 4) and physical variables for both rainbow and cutthroat trout.

Potential Stock Structure

Potential structure was defined as the best possible, (i.e. under no exploitation). We used an age-structured population model, MOCPOP (Beamesderfer 1988), to simulate size structures possible with the range of growth and natural mortality observed in Idaho.

We used a sensitivity analysis to describe the range of possible results. We held all parameters constant and independently varied parameters for growth and natural mortality.

A summary of parameters used in the simulations is presented in Table 1. Documented growth across the state (excluding brook trout) ranged from about 200 to 450 mm at age 4. We assumed slower growth occurs in unstudied headwater streams and used growth rates from 175 to 450 mm at age 4. Growth was described with the Von Bertalanffy model (Ricker 1975). In some cases, we were unable to fit observed growth with that model. In those cases, we built curves that approximated empirical growth data, but did fit the model.

Table 1. Summary of parameters used in stock structure simulations.

Parameters for	Estimate or equation[a]	Source
Growth-LAA4[b]=		
175-trib. streams	$L=986\ (1-e^{-.05(Age-0.09)})$	Theoretical
200-SF Salmon CT	$L=910\ (1-e^{-.06(Age-0.12)})$	Modified from Thurow 1987
222-St. Joe River CT	$L=966\ (1-e^{-.07(age-0.11)})$	Johnson & Bjornn 1978
277-MF Boise River RB	$L=965\ (1-e^{-.07(Age-0.11)})$	Theoretical
343-SF Snake River CT	$L=637\ (1-e^{-.0.21(Age-0.34)})$	Moore & Schill 1984
406-Blackfoot River CT	$L=610\ (1-e^{-0.27(Age-0.21)})$	Modified from Thurow 1981
461-SF Snake River BN	$L=807\ (1-e^{-0.24(Age-0.52)})$	Moore & Schill 1984
Recruitment	Constant - 10,000	-
Natural Mortality[c]		
High	0.50	Rieman 1989 and this report
Low	0.30	
Excessive	0.70	

[a]in each equation L = length in millimeters.
[b]LAA4 = length at age 4.
[c]Conditional natural mortality as a proportion assuming no other mortality is operating on the population.

VTABS

Based on our summary of statewide natural mortality, we selected 0.30 to 0.50 as the range in Idaho waters. We included an additional rate (0.70) to provide perspective for where excessive mortality in individual fisheries is suspected. Stock structures were calculated by dividing the total number of fish larger than 200 mm by the numbers greater than 406 and 508 mm.

We assumed age 6 was the upper limit for fish in the simulations. We also assumed natural mortality is constant from age 1 to age 6. Finally, we held recruitment constant during all simulations.

Regulation Comparisons

We chose three growth rates that cover the range commonly observed in Idaho fisheries. Growth rates used in the predictions were based on data from three Idaho waters. However, they approximate rates observed for wild trout in the following waters:

Low (length at age 4 = 200)- South Fork Salmon and fluvial St.Joe River

Medium (length at age 4 = 288)- Middle Fork Boise, Warm River, Medicine Lodge Creek

High (length at age 4 = 352)- South Fork Boise (below dam), Silver Creek, and catch and release section of Big Wood River

We subjected simulated populations growing at these rates to exploitation under different regulation scenarios. Three exploitation rates were examined (0.00, 0.20, and 0.80). Exploitation was turned on or off on individual age classes consistent with 12 regulations that included minimum and maximum sizes and slot limits. A summary of regulations tested and additional parameters used in the modeling is presented in Table 2. We assumed fish could survive one year past ages usually reported in scale analyses. In slow and modest growth populations, this age was seven years. We assumed fish in fast growth waters would survive six years.

Model outputs were numbers of fish in the population larger than 153 and 305 mm and eggs produced. Simulation were run long enough to allow the population to stabilize (i.e. one generation under constant recruitment). We compared predictions to assess which regulations maximized these outputs and which ones produced similar results. The minimum size available to angling gear was assumed to be 153 mm.

Absolute numbers in our simulations were strongly influenced by growth rate. To standardize results, we converted results to proportions of unexploited numbers. This approach shows the relative regulation effects among populations with different growth potentials on a common scale. Stock recruitment functions are not well documented for Idaho wild trout populations. We, therefore, held

Table 2. Summary of parameters used in the statewide regulation simulations.

Parameters for	Estimate or ectuation[a]	Source
Growth-LAA4		
High-358	$L=702\ (1-e^{-.0.18-(Age-0.12)})$	Moore et al. 1979
Medium-288	$L=569\ (1-e^{-.0.19-(Age-0.32)})$	Rohrer 1989
Low-200	$L=794\ (1^{-e-.0.76-(Age-0.15)})$	Thurow 1987
Fecundity	$0.0003*L^{2.57}$	Rieman et al. 1989
Natural mortality[b]		
High	.50	Rieman et al. 1989 & this report
Low	.30	
Recruitment	Constant at 10,000 fish	-
Exploitation		
High	80%	-
Low	20%	-

Simulated Regulations

- General - no size limit
- 6, 12, 14, 18, & 20 inch minimum sizes
- 10 and 12 inch maximum sizes
- 12 to 20, 8 to 16, 12 to 16 slot limits

[a]In each equation L = length in millimeters.

[b]Conditional natural mortality as a proportion assuming no other mortality is operating on the population.

VTABS

recruitment constant in all simulations at 10,000 fish per year. Comparisons among populations can be viewed only on a per recruit basis. Any comparison of predicted numbers will be conservative where recruitment is less than the capacity of the available habitat.

RESULTS

Statewide Data Summary

Population Data

Growth-Estimated length at age 4 ranged from 192 mm to 453 mm for fluvial St. Joe River cutthroat trout and South Fork Snake River brown trout *Salmo trutta*, respectively. We also found substantial variation in species-specific growth rates. In all cases, westslope cutthroat from northern and central Idaho grew slower than Yellowstone cutthroat from waters in southeastern Idaho. Main Snake River fish (Shelly reach) grew faster than any other cutthroat population (Figure 1).

Rainbow growth varied more than cutthroat growth. Length at age 4 ranged from a low of 217 mm on Upper Warm River to 434 mm on the Henrys Fork of the Snake River near Island Park. A number of popular rainbow fisheries, including Silver Creek, Big Lost, South Fork Boise, Big Wood, and Portneuf rivers, had nearly identical growth rates (Figure 2). In contrast to the northern cutthroat streams, many of the slower-growing rainbow trout populations tended to be tributary streams for more important fisheries.

Cutthroat growth was usually slower than rainbow trout in most Idaho waters. Exceptions were three high conductivity waters in southeast Idaho where cutthroat growth was similar to that of most rainbow (Figure 3).

Growth of rainbow trout was not significantly correlated with conductivity (Figure 4). Rainbow trout growth was correlated to stream width ($p < 0.01$) (Figure 5), but two points had a major influence on the relationship. Cutthroat trout growth was significantly related to conductivity ($p < 0.001$). A summary of all back-calculated length at ages for rainbow and cutthroat populations are in Appendix B. Summaries for brown and brook trout are in Appendix C.

Trout Densities-Trout density was significantly ($p < 0.001$) related to stream width (Figure 6). Small tributary streams contained higher densities of wild trout than those in excess of 10 m width. Nearly all population estimates for stream widths in excess of 50 m came from Region 6 in southeastern Idaho (Figure 7). Estimated densities of fish in these streams ranged from almost 0 fish/100 m^2 in the case the Snake River near Shelly to a high of almost 7 fish/100 m^2 on the special regulation segment of the Henrys Fork. The majority of these estimates include only fish in excess of 150 mm. Variation in density among sites was usually low (±25% of the mean or less).

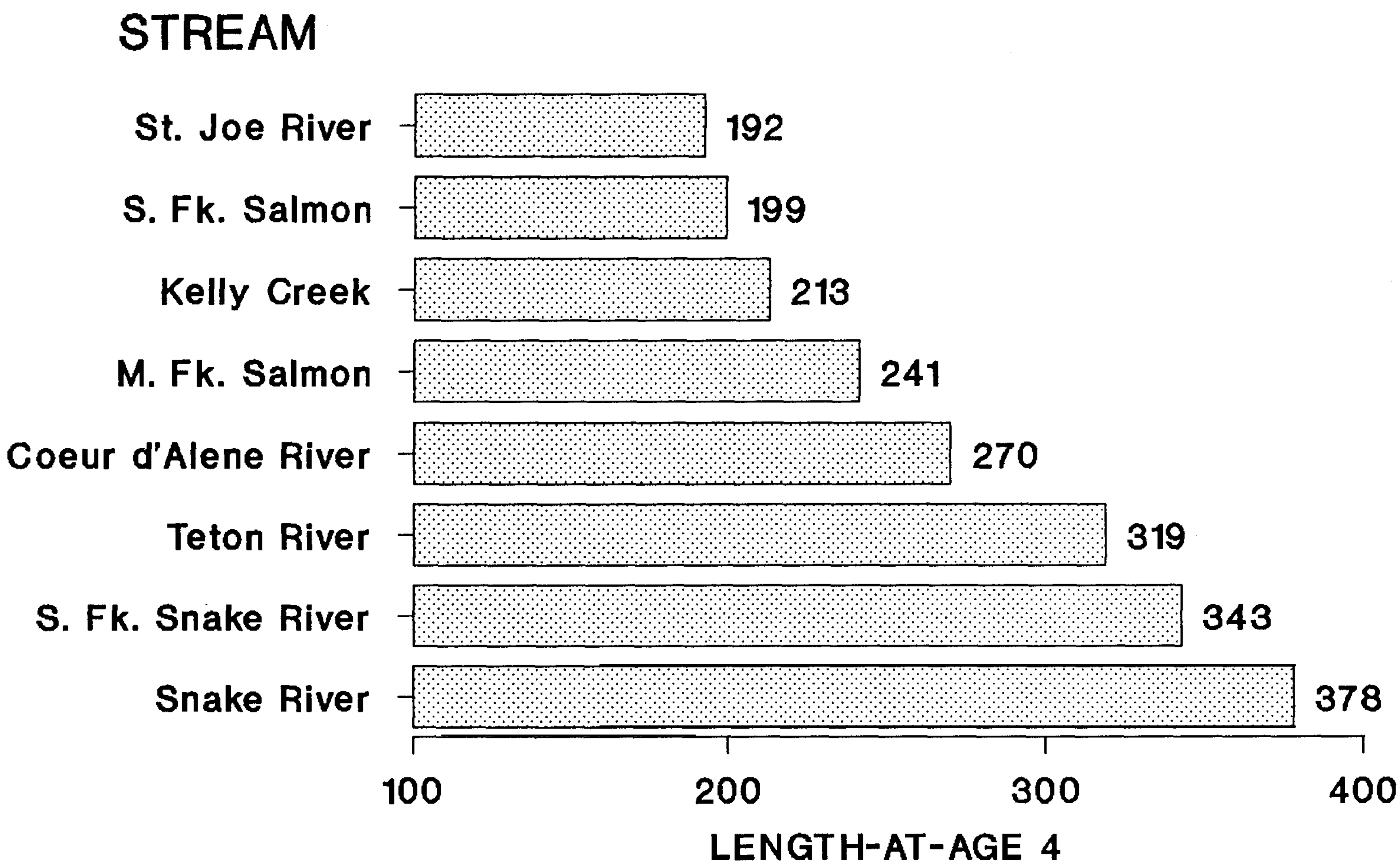


Figure 1. Back-calculated length at age 4 (mm) for fluvial cutthroat trout in eight Idaho streams.

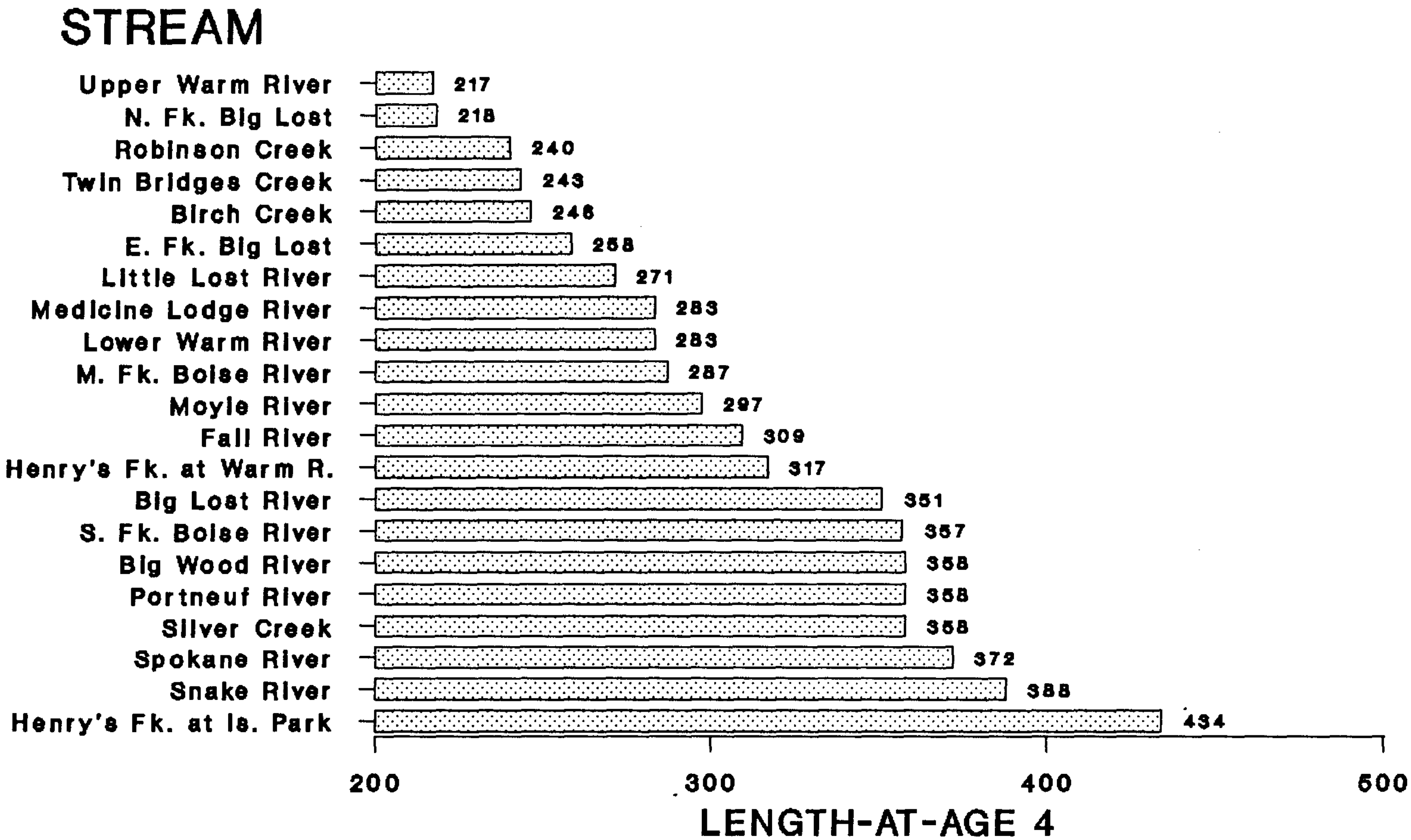


Figure 2. Back-calculated length at age 4 (mm) for fluvial rainbow trout in 21 Idaho streams.

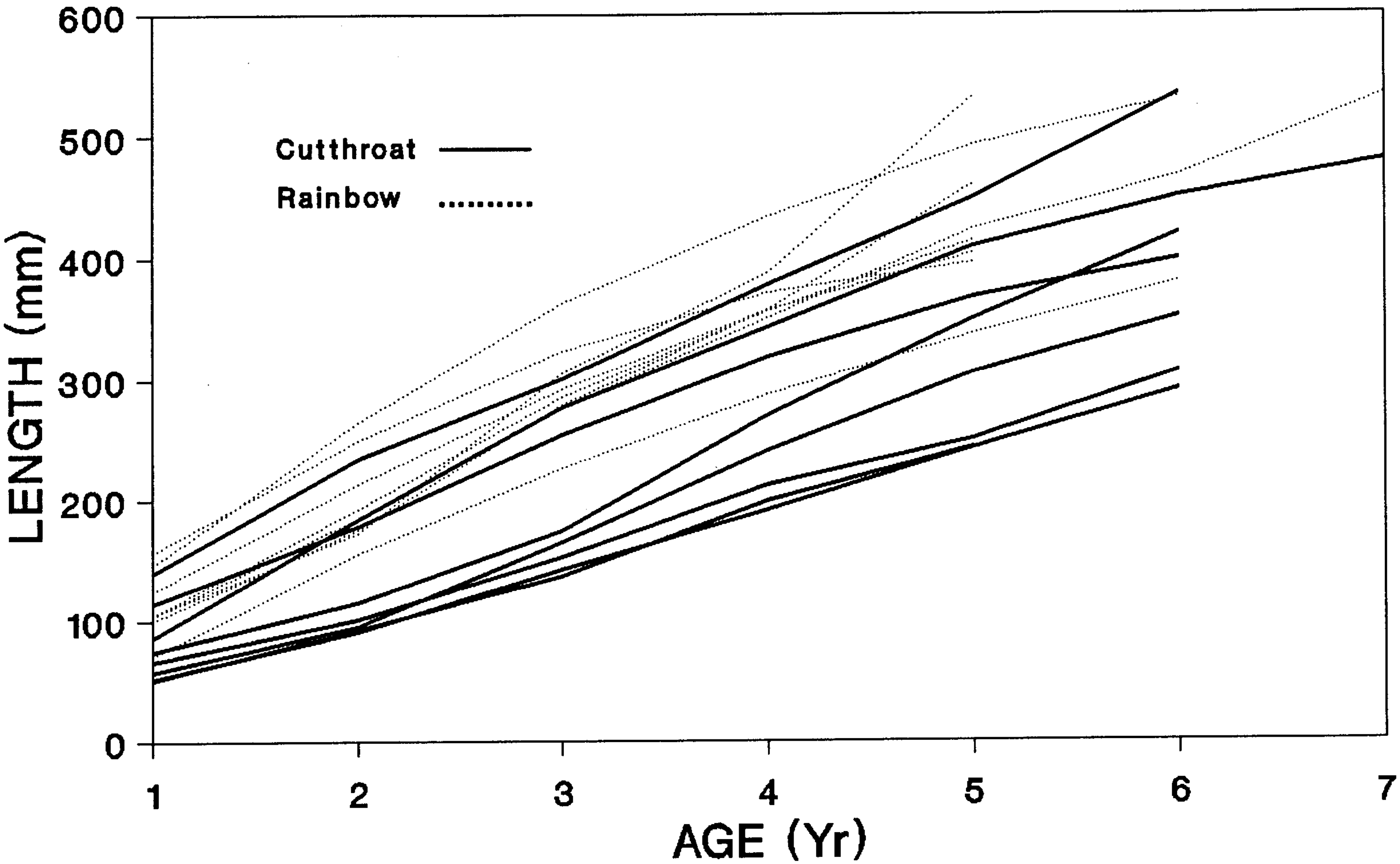


Figure 3. Comparison of back-calculated length at age (mm) for fluvial rainbow and cutthroat trout populations in major Idaho fisheries.

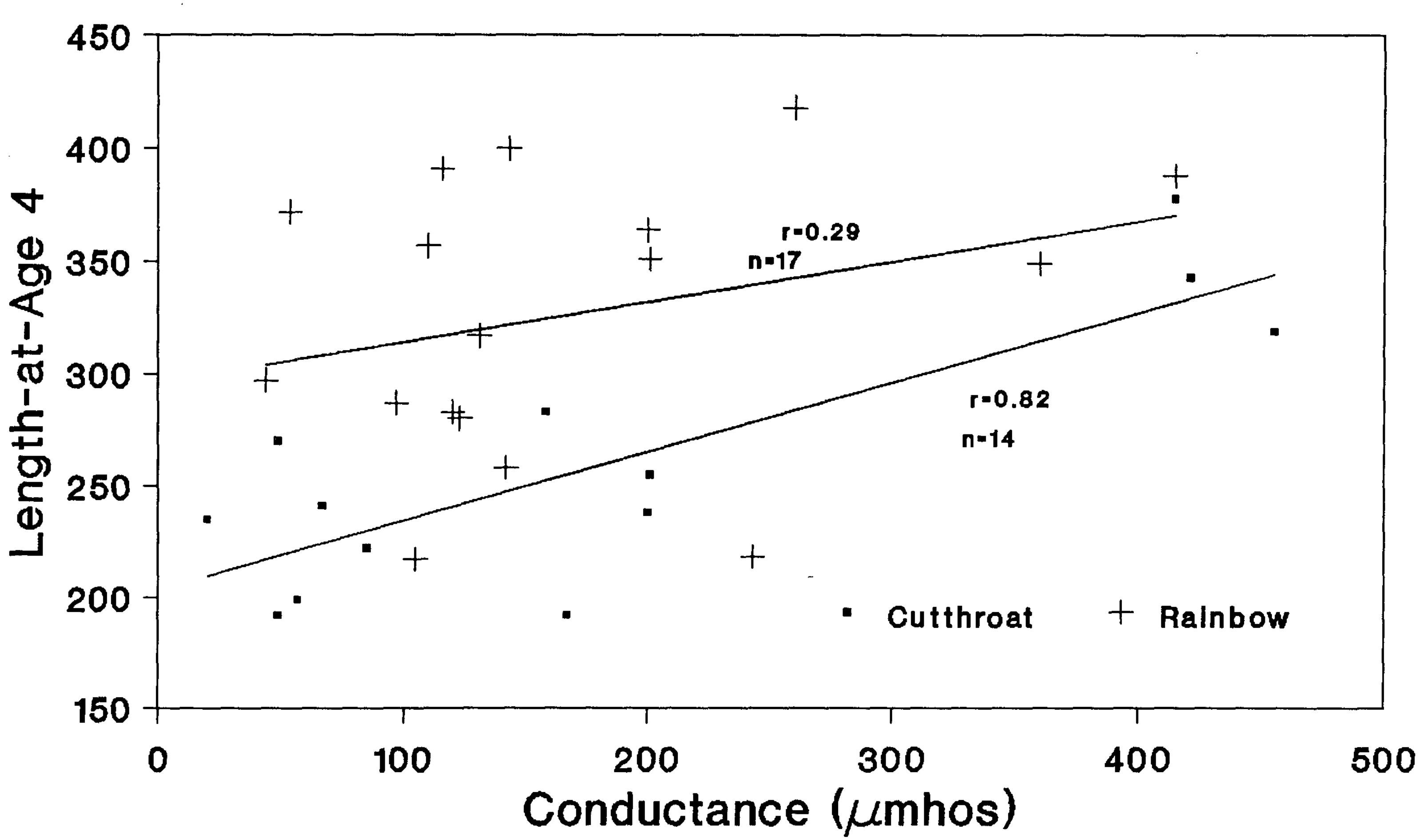


Figure 4. Back-calculated length at age 4 (mm) vs late summer conductivity for fluvial rainbow and cutthroat populations in Idaho and Yellowstone National parks.

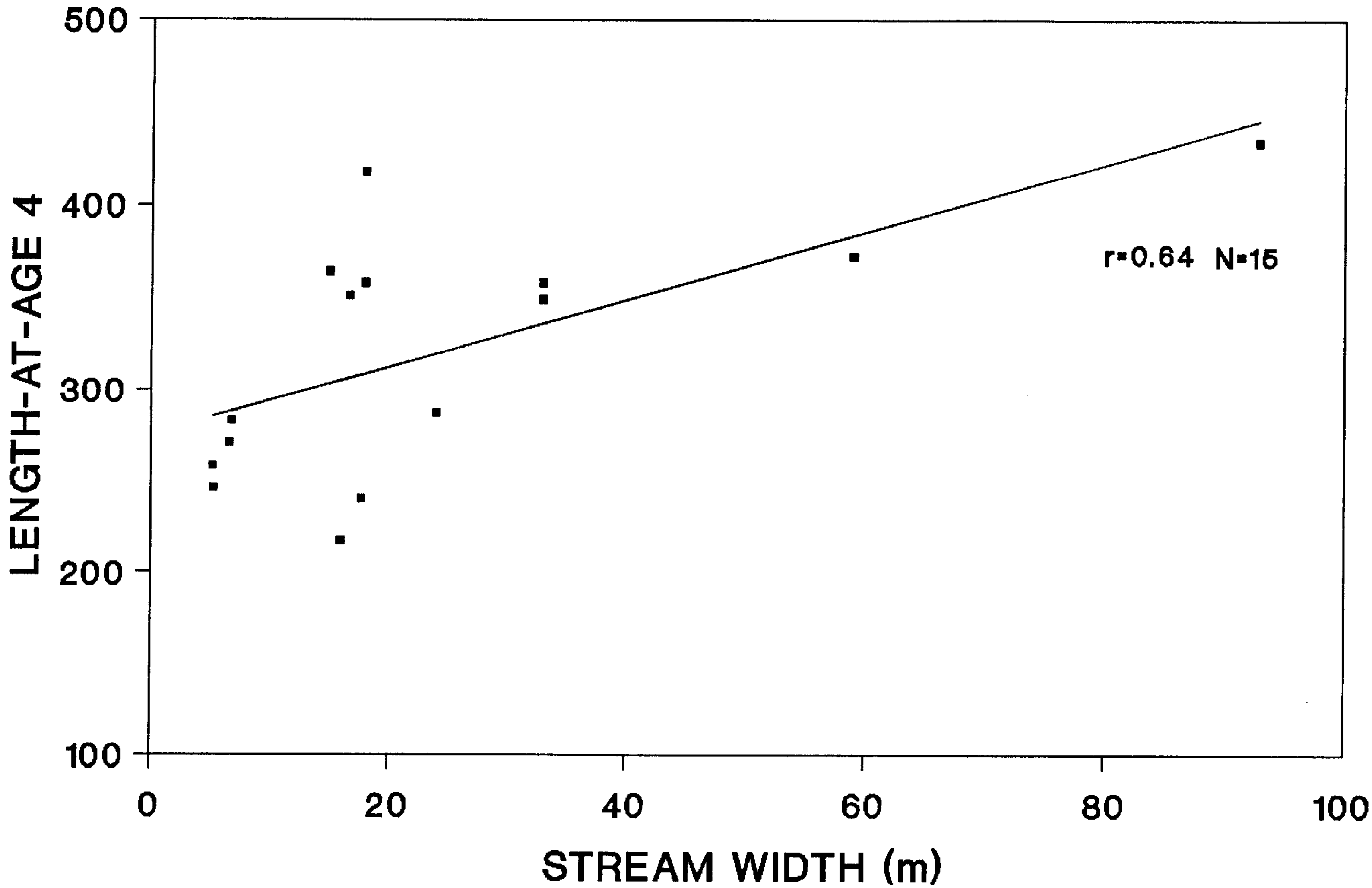


Figure 5. Back-calculated length at age 4 (mm) vs stream width for fluvial rainbow trout populations in Idaho.

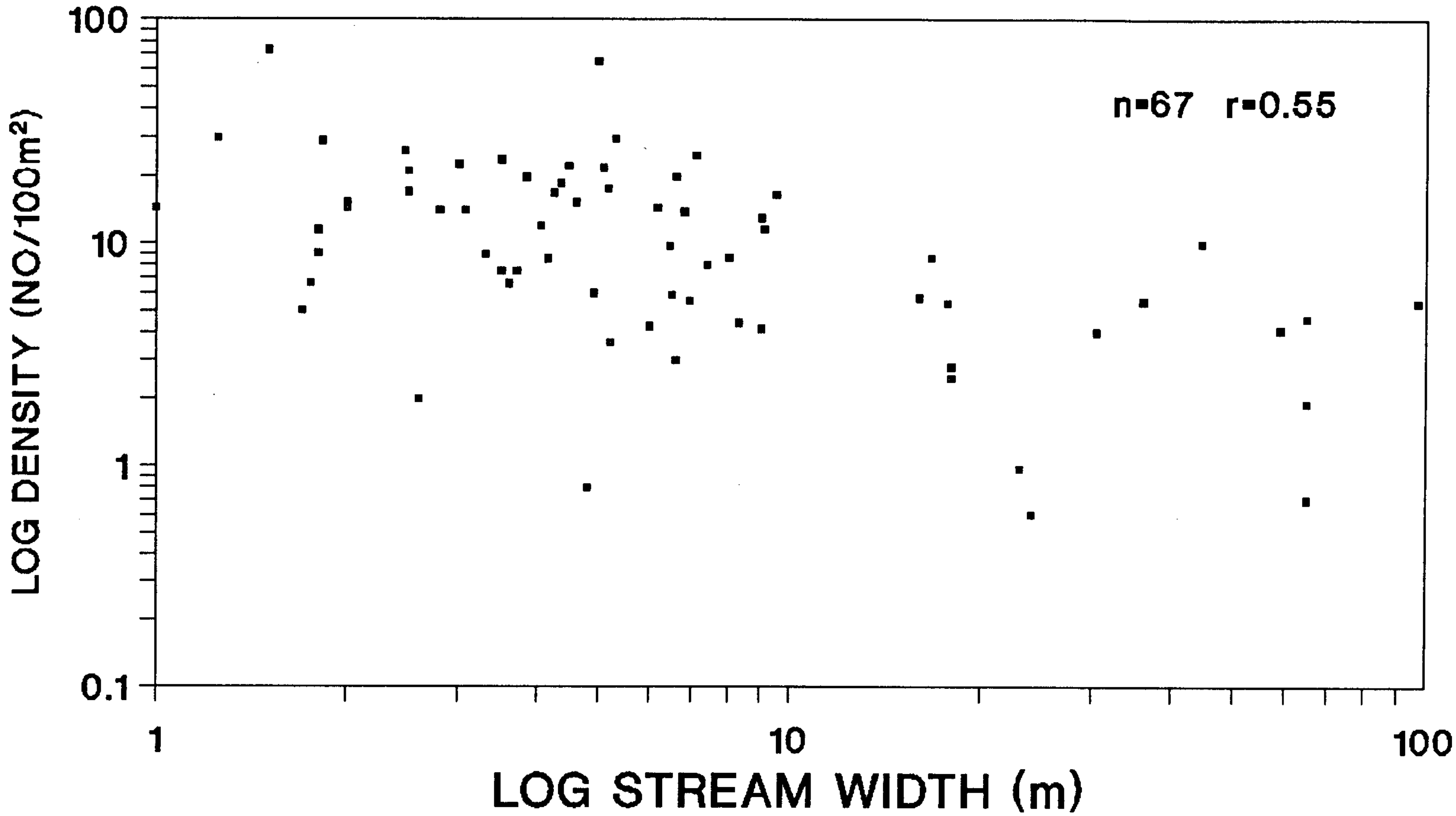


Figure 6. Densities of age 1+ wild trout (number/100 m^2) vs stream width (m) in fluvial Idaho populations.

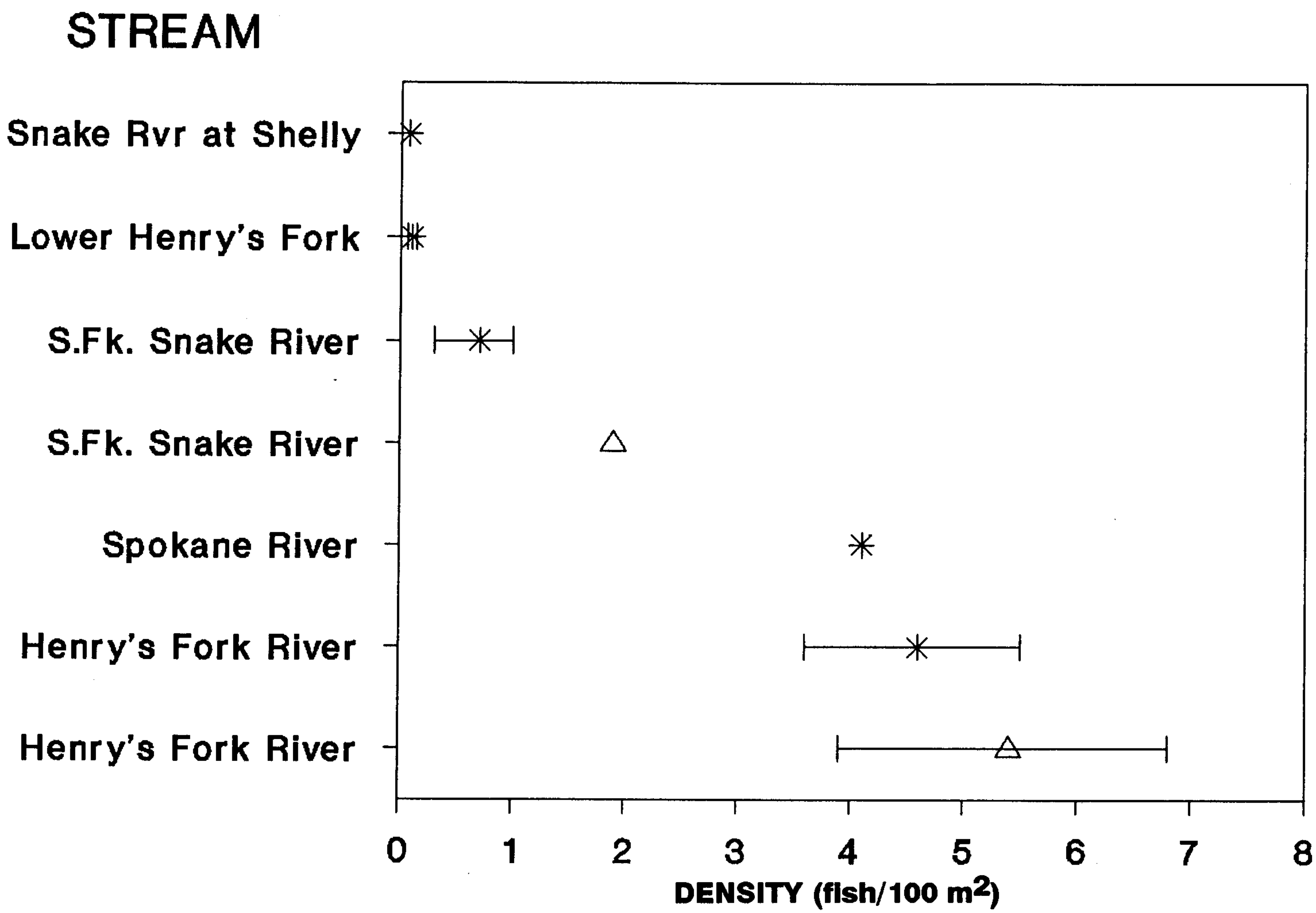


Figure 7. Densities of fluvial wild trout (fish/100 m^2) in Idaho waters over 50 m wide. Bars depict range of densities at various sites in the same stream. Triangles denote special regulation waters.

There was a wider range of trout densities in streams ranging from 10 to 50 m in width (Figure 8). The Middle and North Forks of the Boise River both contained the lowest densities at about 1 fish/100 m^2. The highest densities were in a general regulation segment of the Big Lost River immediately below Mackay dam (12 fish/100 m^2). The Buffalo River in Region 6 also contained good numbers of fish, but small brook trout accounted for most of the population. Individual population estimates for streams in this size group often ranged from 50% to 70% about the mean.

We found large amounts of data on Idaho tributary streams less than 10 m in width. Much of this data is not comparable, however. Unusable data was expressed in linear terms (fish/100 m) or as number of trout per snorkeling transect. The most complete data were from southeastern Idaho (Figure 9). Estimated trout densities in 124 sites in IDFG Regions 5 and 6 ranged from nearly 0 to 87 fish/100 m^2. Forty percent of all sites sampled had densities of less than 10 fish/100 m^2. However, stations with densities in excess of 20 fish/100 m^2 were common.

Standinq Crop-Only seven studies with documented standing crop estimates were found in Idaho. Weights were rarely reported. Data were insufficient for characterizing Idaho populations.

Size Structure-The estimated size structure for populations determined by electrofishing is presented in Table 3. PSD estimates ranged from a low of 1% for the Birch Creek population to 63% for the Nature Conservancy section of Silver Creek. Special regulation segments of the Henrys Fork, Silver Creek, and the Big Wood River all had higher PSD estimates than nearby general regulation segments. A more pronounced difference between general and special regulation segments was obvious when comparing fish in excess of 406 mm (QSD).

Few streams had appreciable numbers of rainbow or cutthroat in excess of 508 mm (Table 3). A general regulation segment of the Portneuf River had the highest TSD of 3%.

A number of additional reports contained length frequency data in graphical form. In many cases, however, sample sizes were too low or other information needed to generate numerical summaries was not available.

Natural Mortality-Estimates of conditional natural mortality in Idaho wild trout streams ranged from 0.31 to 0.64. The lowest estimate was for the Upper St. Joe River and the highest was for the Spokane River (Figure 10). Most estimates ranged between 0.30 and 0.50. I used that range in subsequent modeling.

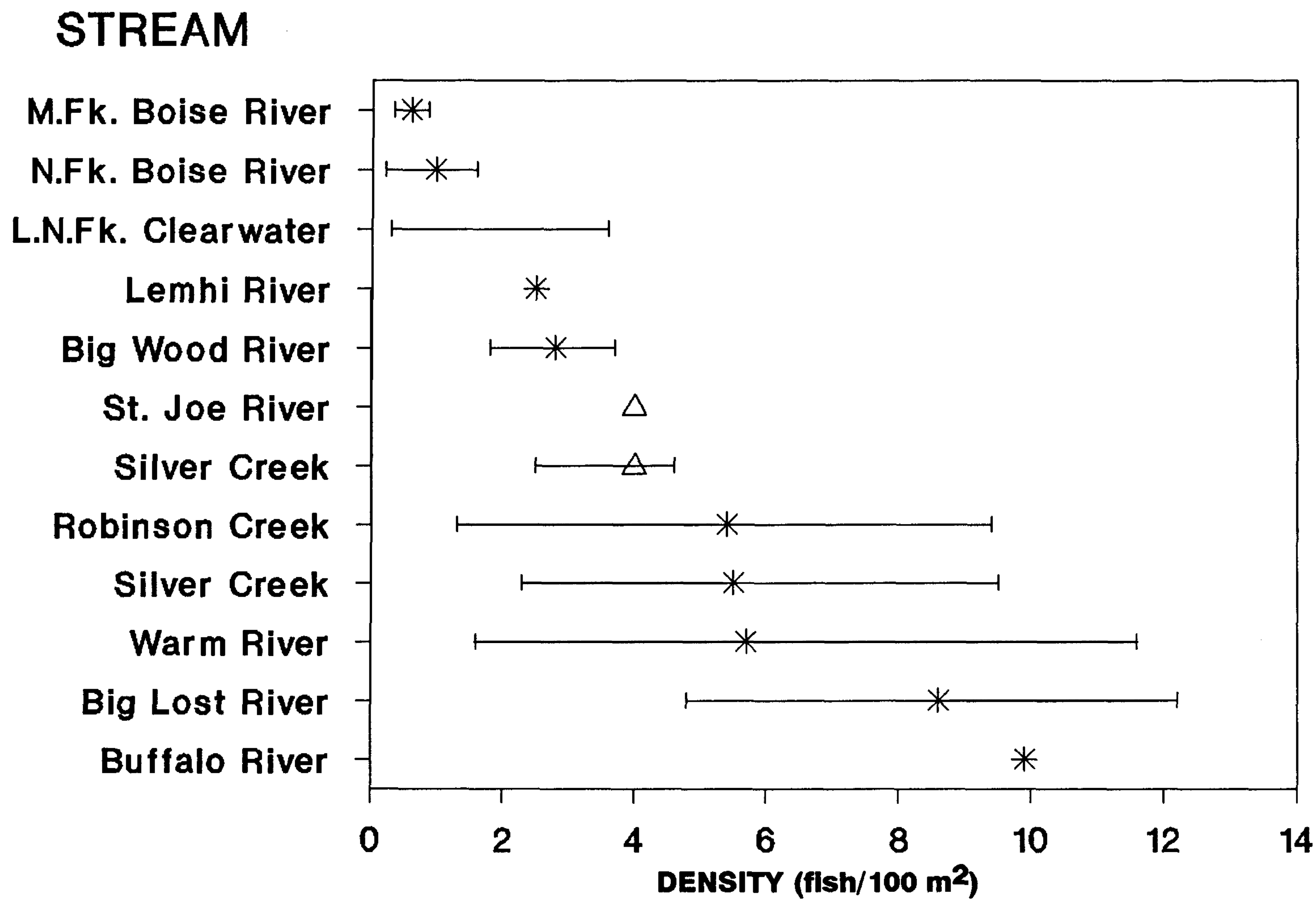


Figure 8. Densities of fluvial wild trout (fish/100 m^2) in Idaho waters from 10 to 50 m in width. Bars depict range of densities at various sites in the same stream. Triangles denote special regulation waters.

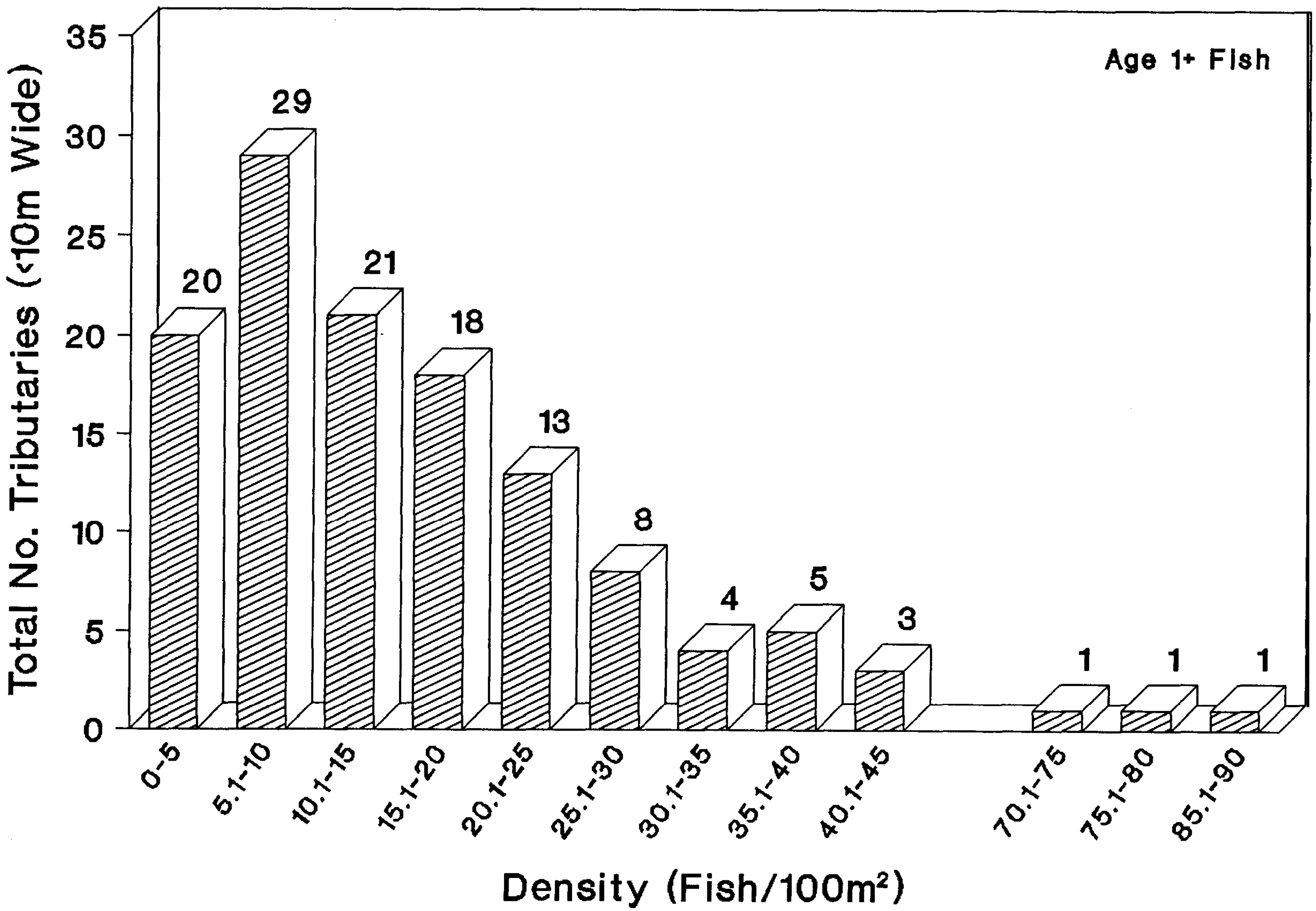


Figure 9. Frequency distribution of wild trout densities within individual sampling sites in Regions 5 and 6 as estimated by electrofishing. All streams are less than 10 m wide.

Table 3. Population structure for wild trout fisheries in Idaho based on electrofishing samples[a].

Stream	Section	Width	Stock structure[b] % >305	% >406	% >50	Species
Henrys Fork R.	RR Ranch & Box Canyon	97	4	27	2	RB
Henrys Fork R.	Pine Haven & Cardiac	65	7	1	.2	RB
Silver C.	Kilpatric & Priest	36	42	8	.2	RB
			50	42	15	BN
Silver C.	Nature Conservancy		6	25	0	RB
		30	40	40	24	BN
MF Boise R.	Mean for entire stream	24	4	N/A	0	RB
NF Boise R.	Mean for all sections	23	13	N/A	0	RB
Big Wood R.	Sections 2,3,4	18	21	5	.05	RB
Big Wood R.	C & R	18	20	4	.4	RB
Portneuf R.	Above Lava Hot Springs	18	4	17	3	RB,CT
Big Lost R.	Near Arco & below Mackay	17	48	4	.02	RB
Birh C.	Mean of sections	10	1	0	0	RB,BK
Stalker C.	1 section	9	42	15	1	RB,BN
Little Lost R.	4 sections	7	3	0	0	RB,BK

[a]Big Wood River corrected for electrofishing size bias, all others not corrected.
[b]Based only on those fish >200 mm in length.

VTABS

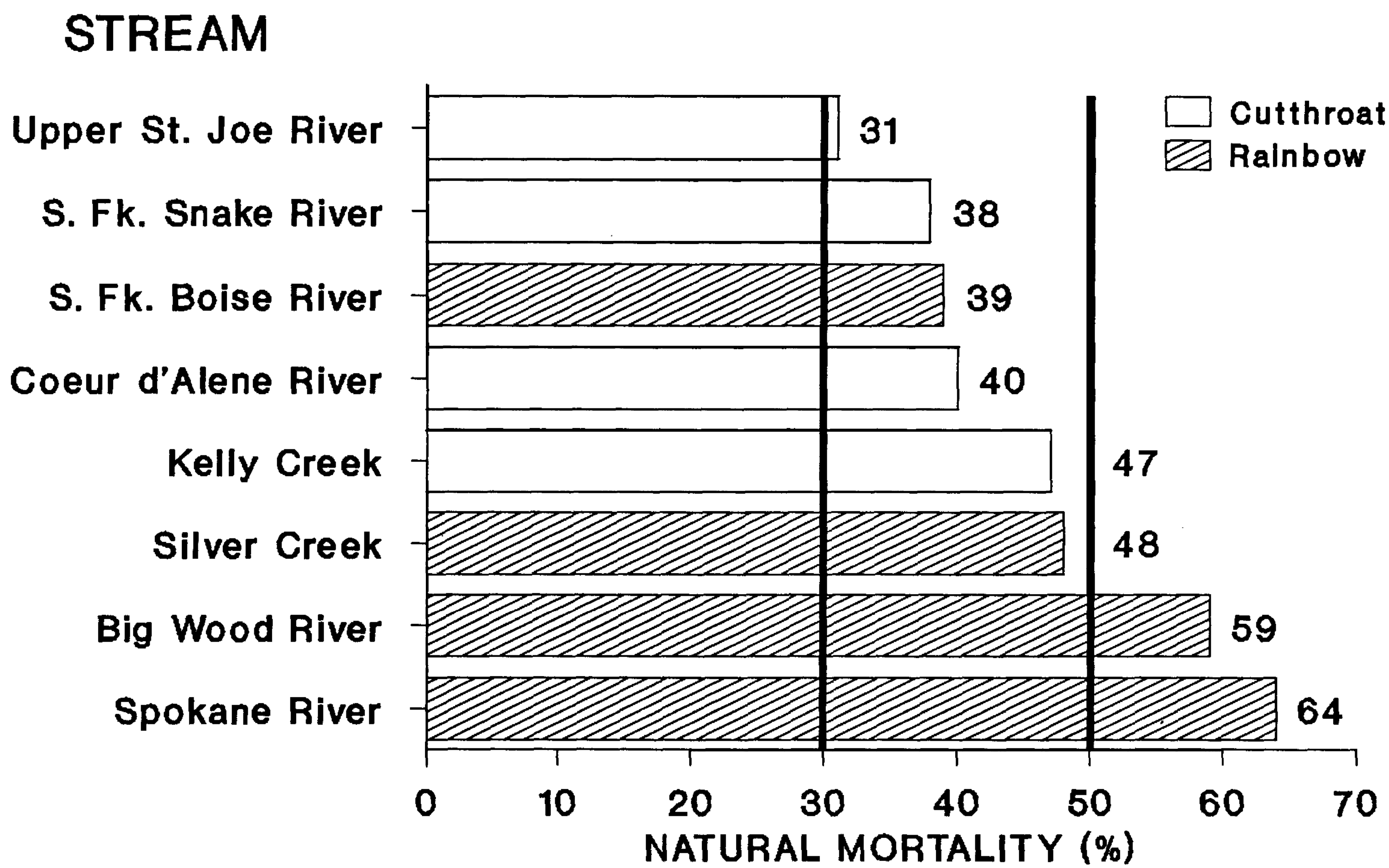


Figure 10. Estimates of conditional natural mortality rates for Idaho wild trout populations from past studies.

Fisheries Data

Angler Effort-Most data were reported in total hours or h/km. Estimates of effort per surface area were often not available. Annual estimates of angler use ranged from 96 to 2,726 h/km (Figure 11).

Annual effort h/hectare/year ranged from a low of 70 h/hectare on the Snake River near Shelly to over 1,100 h/hectare on the Nature Conservancy segment of Silver Creek (Figure 12). Angler effort on a general regulation segment of McCoy Creek, a small (5 m to 10 m wide) stream in southeastern Idaho, approached that observed on Silver Creek.

Harvest-Nearly all wild trout streams in the summary effort were also planted with hatchery rainbow trout. We could not confidently estimate wild trout catch (harvest + release) rates. We were able to separate wild and hatchery trout harvest in most cases. Season-long harvest rates ranged from a low of 0.05 fish/h on the Boise River in downtown Boise to 0.43 fish/h on the Big Wood River. About half of the streams in the summary sustained harvest rates between 0.22 and 0.28 fish/h (Figure 13, Appendix D-2).

Few estimated harvest rates were below 0.17 fish/h. The South Fork Boise River above Anderson Ranch had the lowest harvest rate. The Big Wood, Teton, and South Fork Snake rivers had the highest harvest rates.

Weights of fish were rarely reported, thus, we could not compare weights or yield in the fisheries.

Potential Stock Structure

Natural mortality had a large effect on predicted size structure (Figure 14). Where natural mortality is high (70% in the model), very few fish exceeded 406 mm (QSD) no matter what growth rates were. Model results did not always compare closely with QSD estimates of size structure from actual catch-and-release fisheries (Table 4).

The model predicted few trout over 508 mm (TSD) when growth was less than 400 mm at age 4 (Figure 15). Our results were similar to estimated TSD on sections of the Big Wood and Silver Creek. Predicted TSD for the Henrys Fork did not agree with observed estimates (Table 4).

The model predicted a TSD of about 20% for the best growth in Idaho (i.e. South Fork Snake River brown trout) and with low natural mortality. The predicted estimates approached 25% if fish commonly lived to age 7.

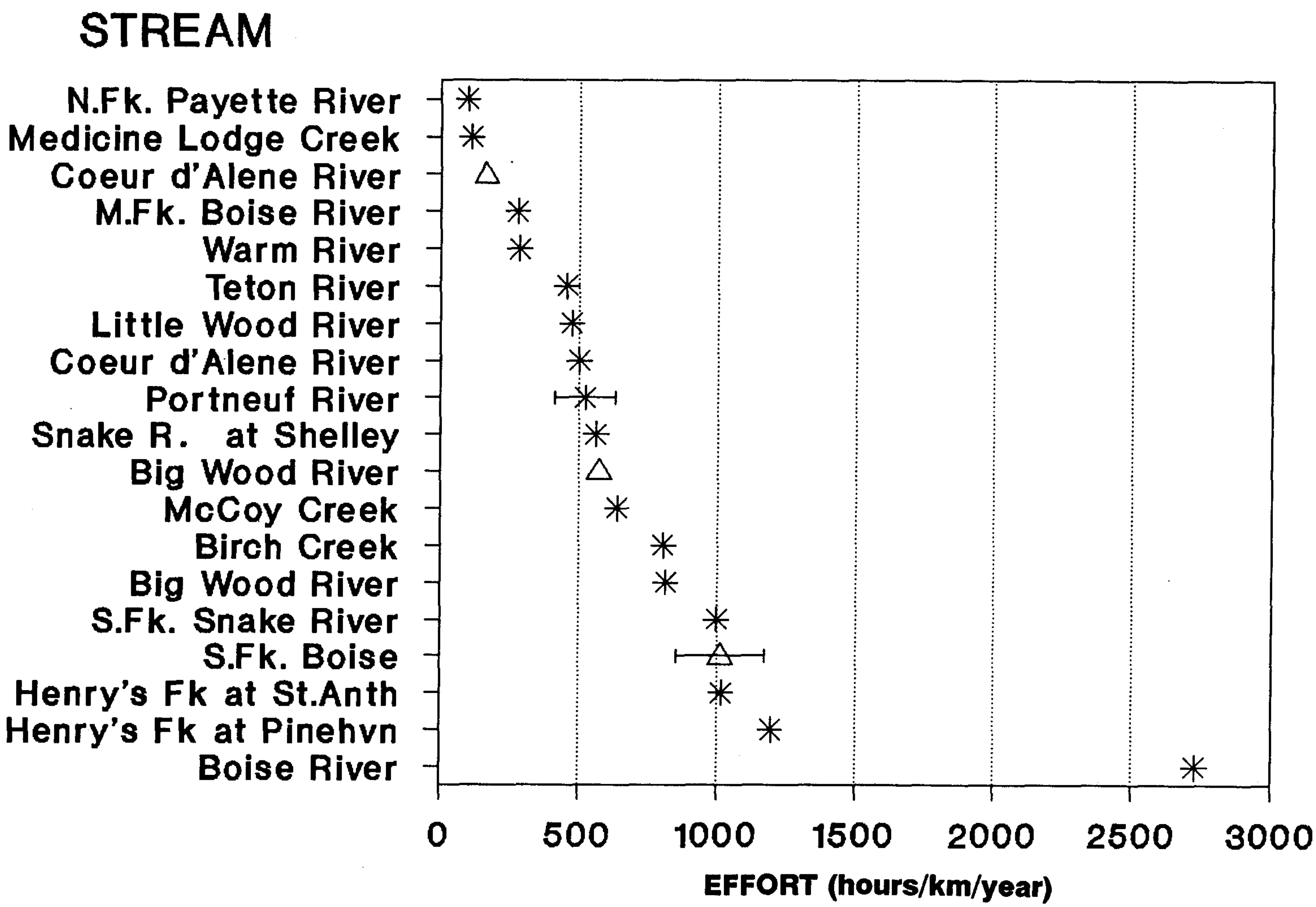


Figure 11. Creel census estimates of angler effort (hours/km/year) for available Idaho waters containing wild trout. Triangles denote special regulation waters.

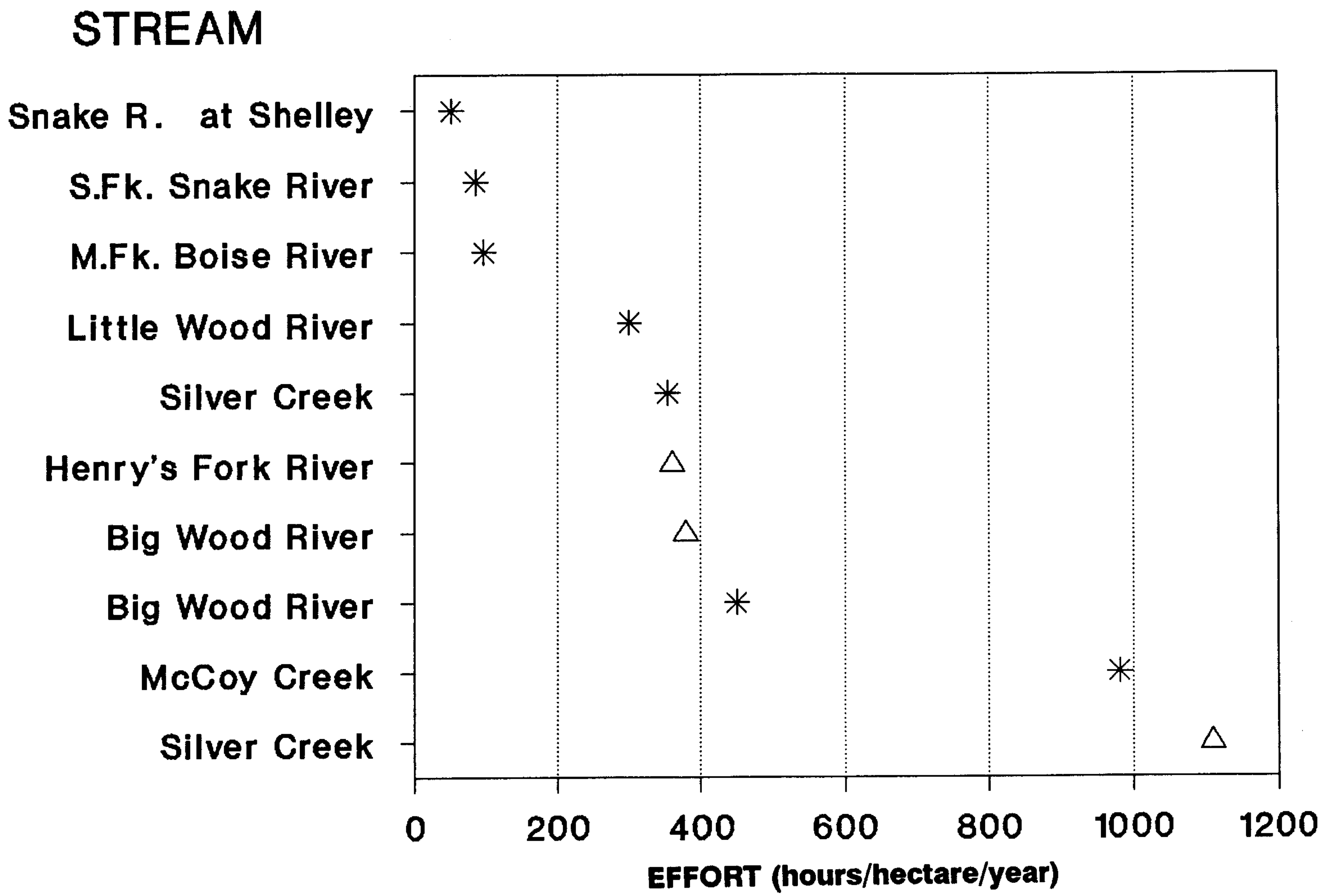


Figure 12. Creel census estimates of angler effort (hours/hectare/year) for available Idaho waters containing wild trout. Triangles denote special regulation waters.

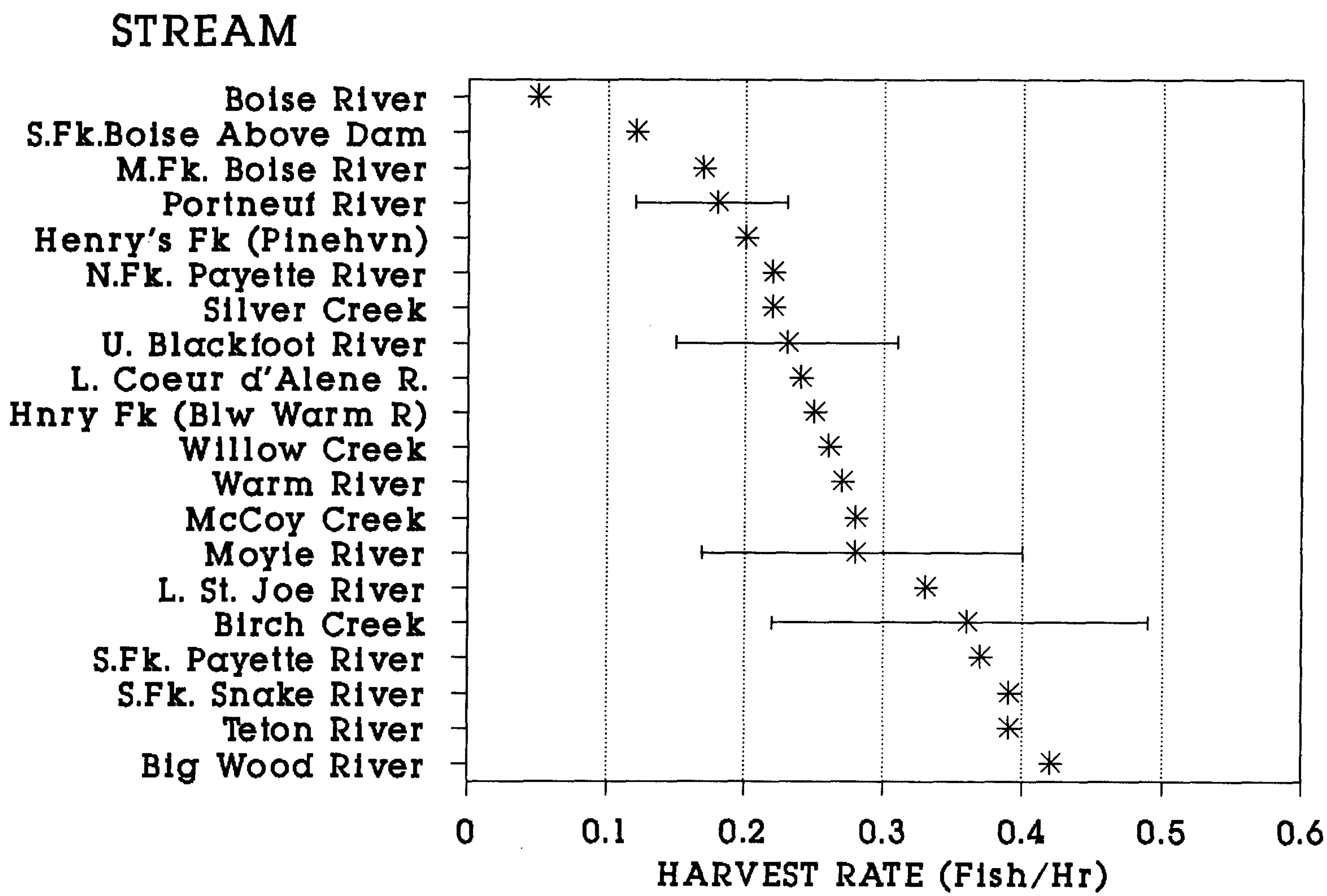


Figure 13. Estimated harvest rates (fish/hour) of wild trout in various Idaho fisheries. Bars depict ranges when more than one year was censused.

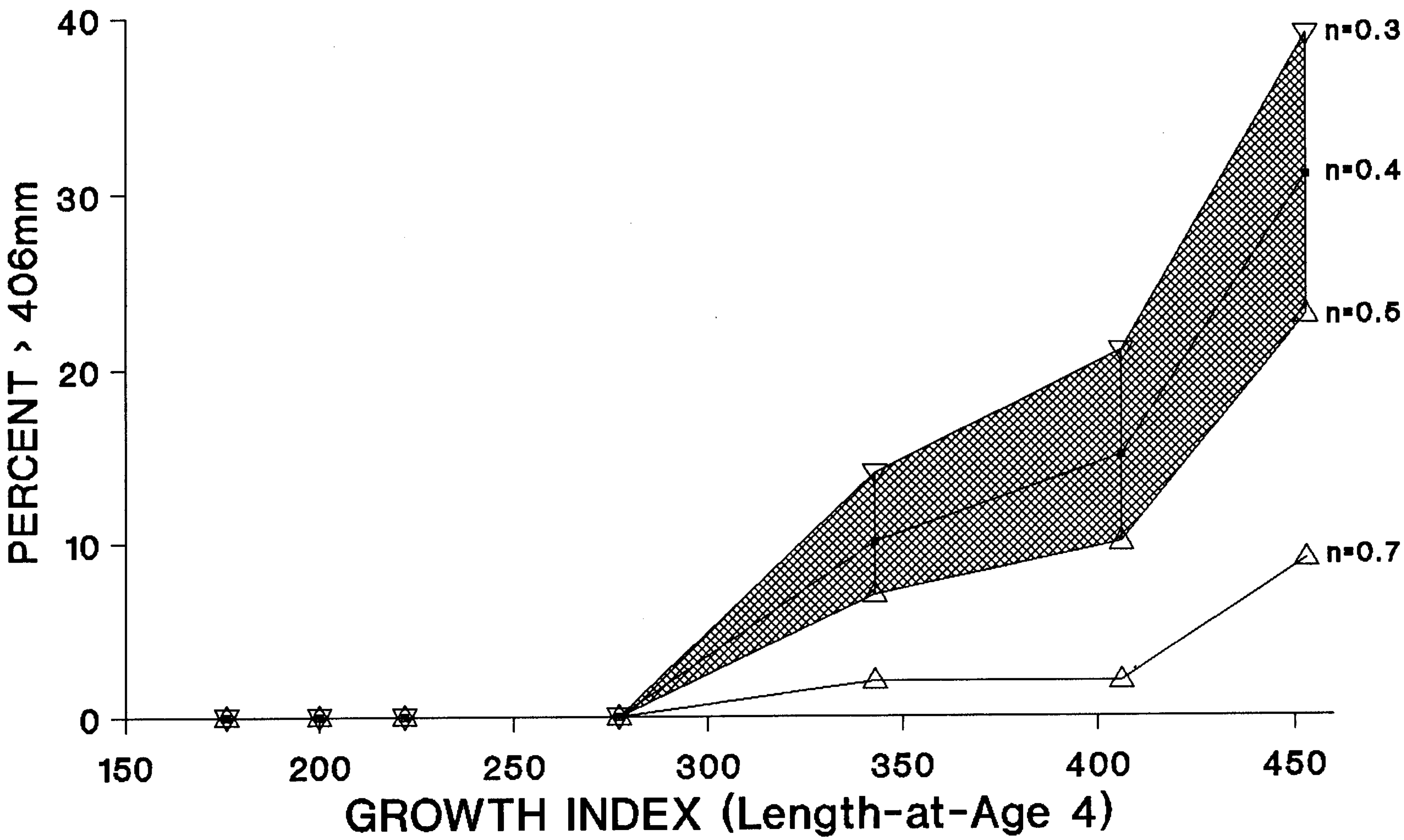


Figure 14. Simulations of potential quality size structure (PSD >406 mm) for wild trout populations in Idaho with no exploitation, constant recruitment and varied rates of growth and natural mortality (n). Points represent growth range in Idaho for all species. Dark band represents likely range of natural mortality. Actual parameters used for simulations are in Table 1.

Table 4. Predicted and observed stock structures for existing catch-and-release fisheries in Idaho. Predictions based on reported growth and assumed conditional natural mortality range of 0.30 to 0.50.

Stream	Estimated length at age 4	Stock Structure QSD[A] predicted	observed	TSD[b] predicted	observed	Source
Big Wood River	364	8-14	4.0	0	0.05	Thurow 1990
Silver Creek[s]	358	8-14	25.0	0	0	Reihle et al. 1989
Henrys Fork[ed]	434	17-29	26.0	7-15	2	Angradi & Contour 1989
MF Salmon River	241	0.0	0.0			Thurow 1983, K. Ball personal communication

[d]QSD = Quality stock density or proportion of all fish over 200 mm in total length that exceed 406 mm.
[b]TSD = Trophy stock density or proportion of all fish over 200 mm in total length that exceed 508 mm.
[c]Electrofishing data not corrected for size selection.
[d]Assumes no harvest with the 8-20 slot limit.

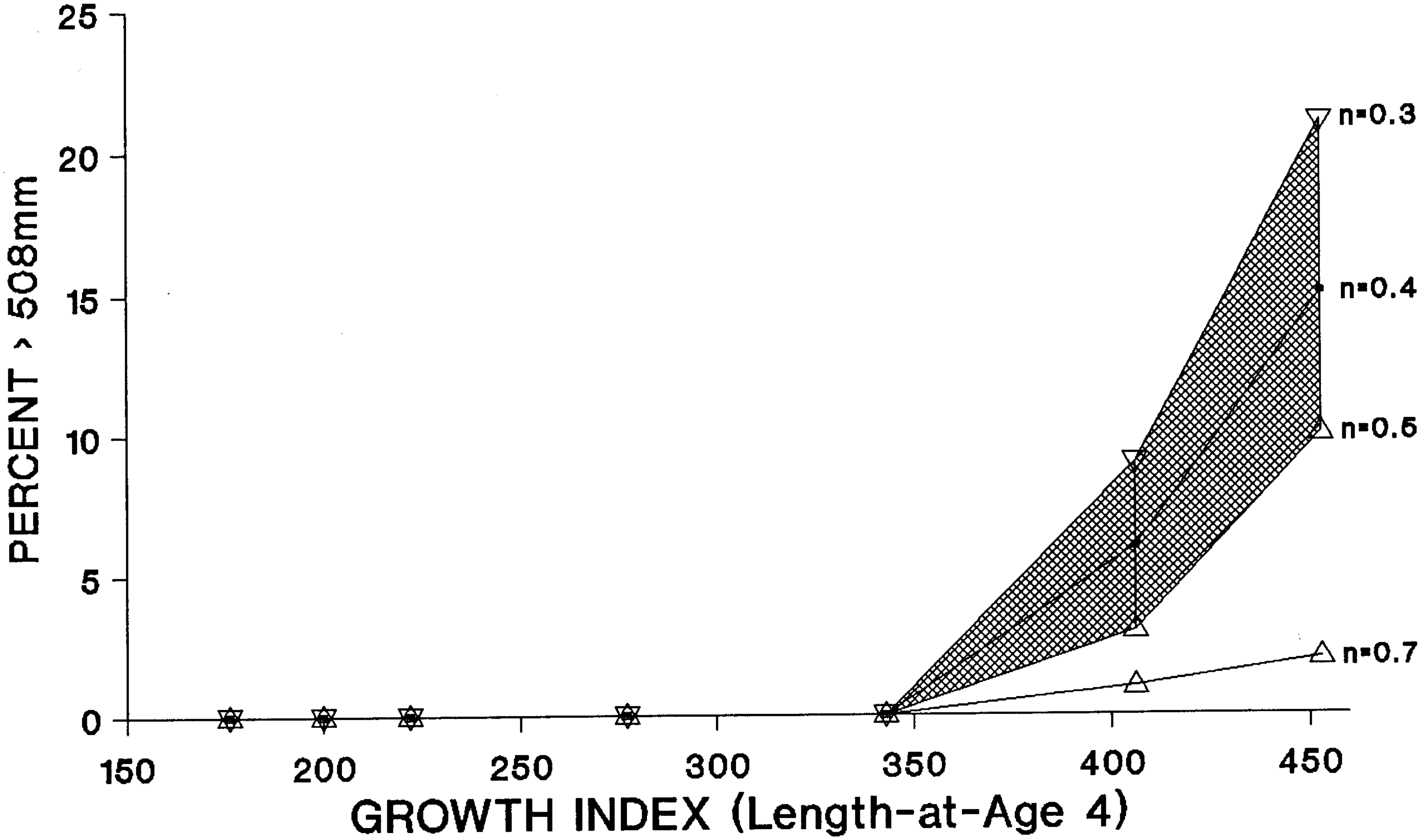


Figure 15. Simulations of potential trophy size structure (PSD >508 mm) for wild trout populations in Idaho with no exploitation, constant recruitment, and varied rates of growth and natural mortality (n). Points represent growth range in Idaho for all species. Dark band represents likely range of natural mortality. Actual parameters used for simulations are in Table 1.

Regulation Comparisons

Predicted numbers of fish increased 1.4- to 3-fold over the range of growth compared. The effect of growth on numbers was greatest for the largest size classes (Figure 16). Growth had a much smaller effect on total number greater than 153 mm. We express subsequent model predictions as a proportion of these unexploited numbers.

Growth had little effect on predicted numbers larger than 153 mm with any of the regulations (Figure 17). Even with heavy exploitation, differences were always less than 25%. Slot limits produced fewer (30e to 50%) total fish than minimum size limits.

Minimum size limits were far more effective than slot limits in increasing numbers larger than 305 mm, especially when exploitation was high (Figure 18). Slot and maximum size limits produced little or no benefit over general regulations when growth was slow or exploitation high. Differences among the individual regulations were small relative to differences among regulation types (e.g. minimum vs maximum or slots). High exploitation resulted in almost complete loss of large fish unless minimum size limits were used.

The effect of regulations on egg production were more sensitive to growth rates, especially at higher exploitation rates (Figure 19). Small minimum size limits were effective with slow growth but not fast growth (i.e. the faster the growth, the larger the minimum size limit necessary to get the same relative response in the population). Slot and maximum size limits did not provide much benefit over general regulation at high exploitation.

DISCUSSION

Statewide Data Summary

The summary results provide some insight as to what to expect in Idaho wild trout fisheries. Conductivity was highly correlated with growth in cutthroat trout. Several large southeast Idaho waters strongly influenced the regression results, however (Appendix A-2). Data from additional smaller streams with conductivities between 200' to 400 umhos would be desirable in evaluating the relationship.

McFadden and Cooper (1962) found a similar relationship between conductance and growth in brown trout in Pennsylvania streams. Others have related conductance to game fish production in streams (Scarneccia and Bergersen 1987; O'Conner and Power 1976).

Growth is an important factor in fish population dynamics and management. Our simulation results indicate growth has a major effect on potential stock structure over ranges observed in Idaho (Figure 14). Our results suggest a simple conductivity measurement can provide some perspective for a manager interested in potential stock-structure of a cutthroat fishery.

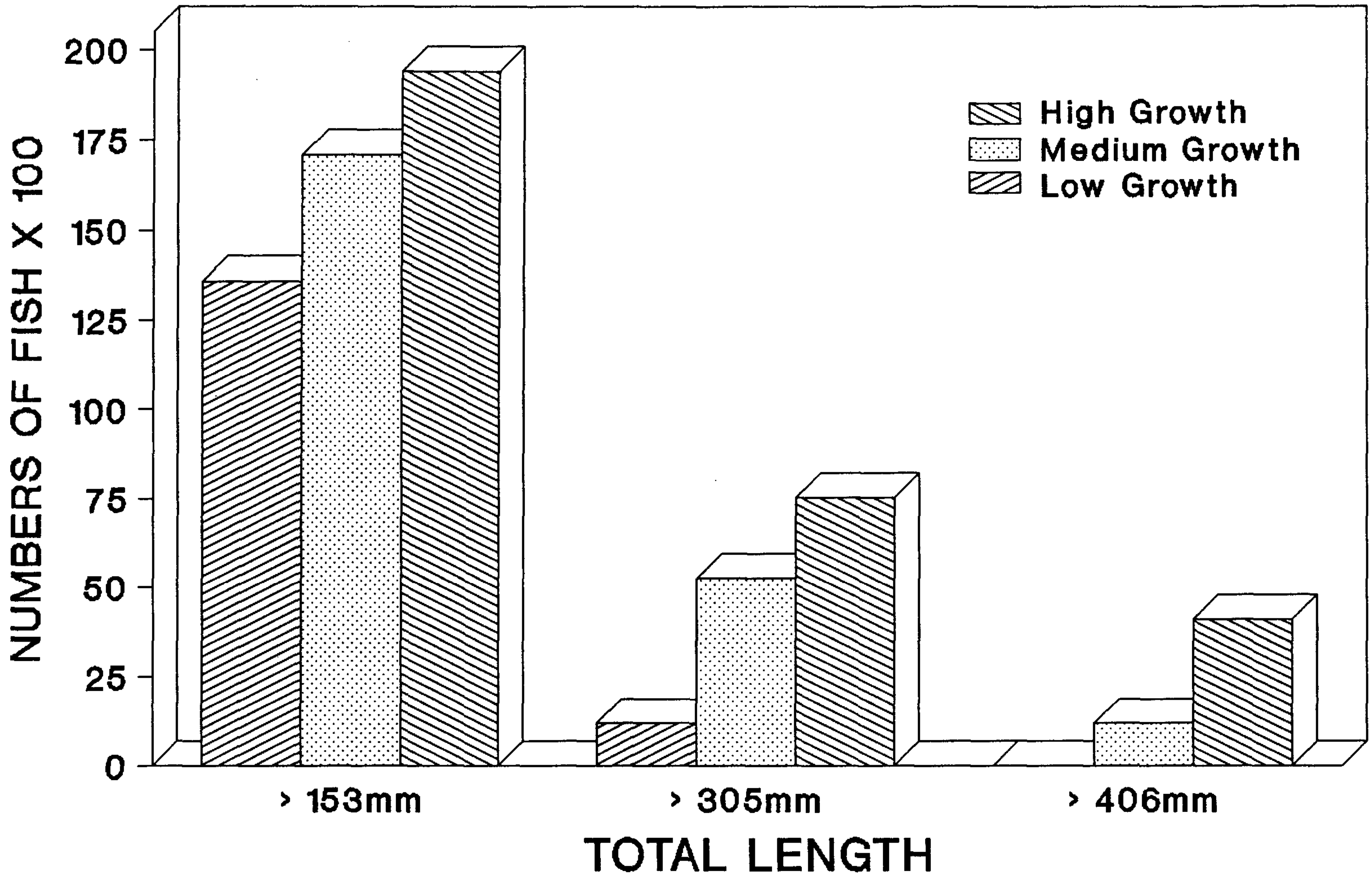


Figure 16. Numbers of trout exceeding various lengths in simulated populations exhibiting three rates of growth and no exploitation. Natural mortality = 0.30 and recruitment constant at 10,000 fish. Other parameters used for simulations in Table 2.

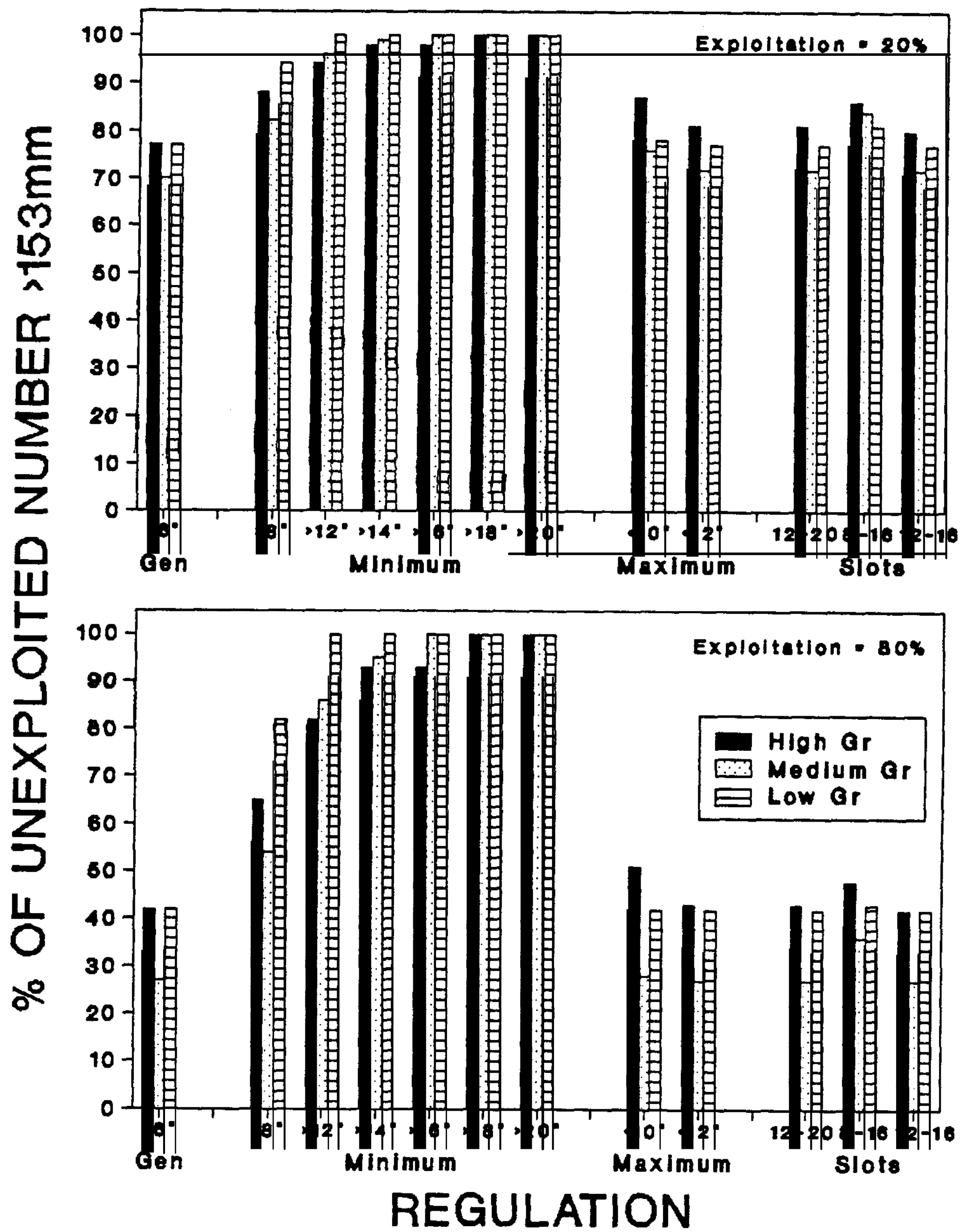


Figure 17. Simulations of trout numbers >153 mm (proportion of unexploited number) for populations with varied growth, exploitation, and harvest restrictions. Natural mortality = 0.30 and recruitment constant at 10,000 fish.

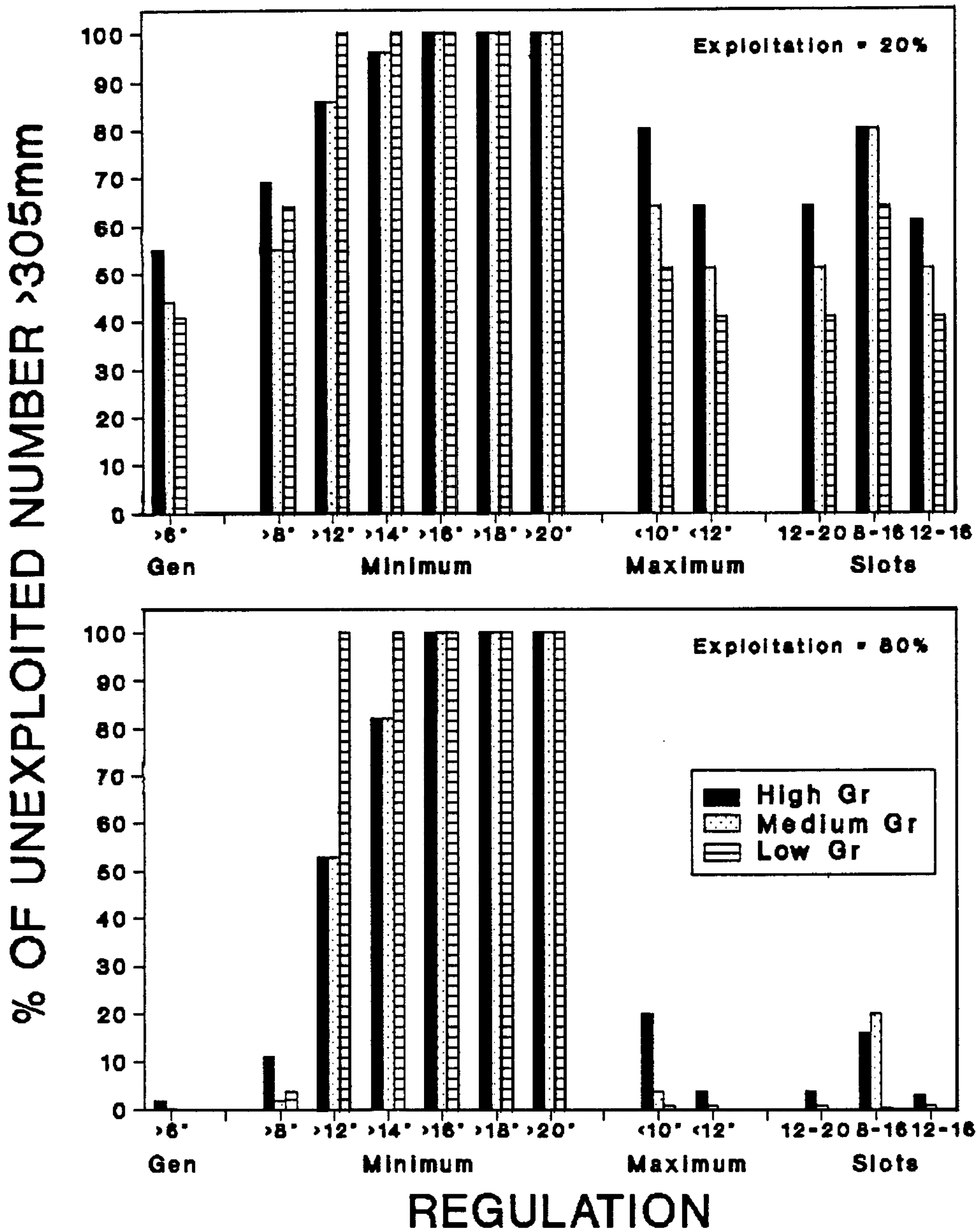


Figure 18. Simulations of trout numbers >305 mm (proportion of unexploited number) for populations with varied growth, exploitation and harvest restrictions. Natural mortality = 0.30 and recruitment constant at 10,000 fish.

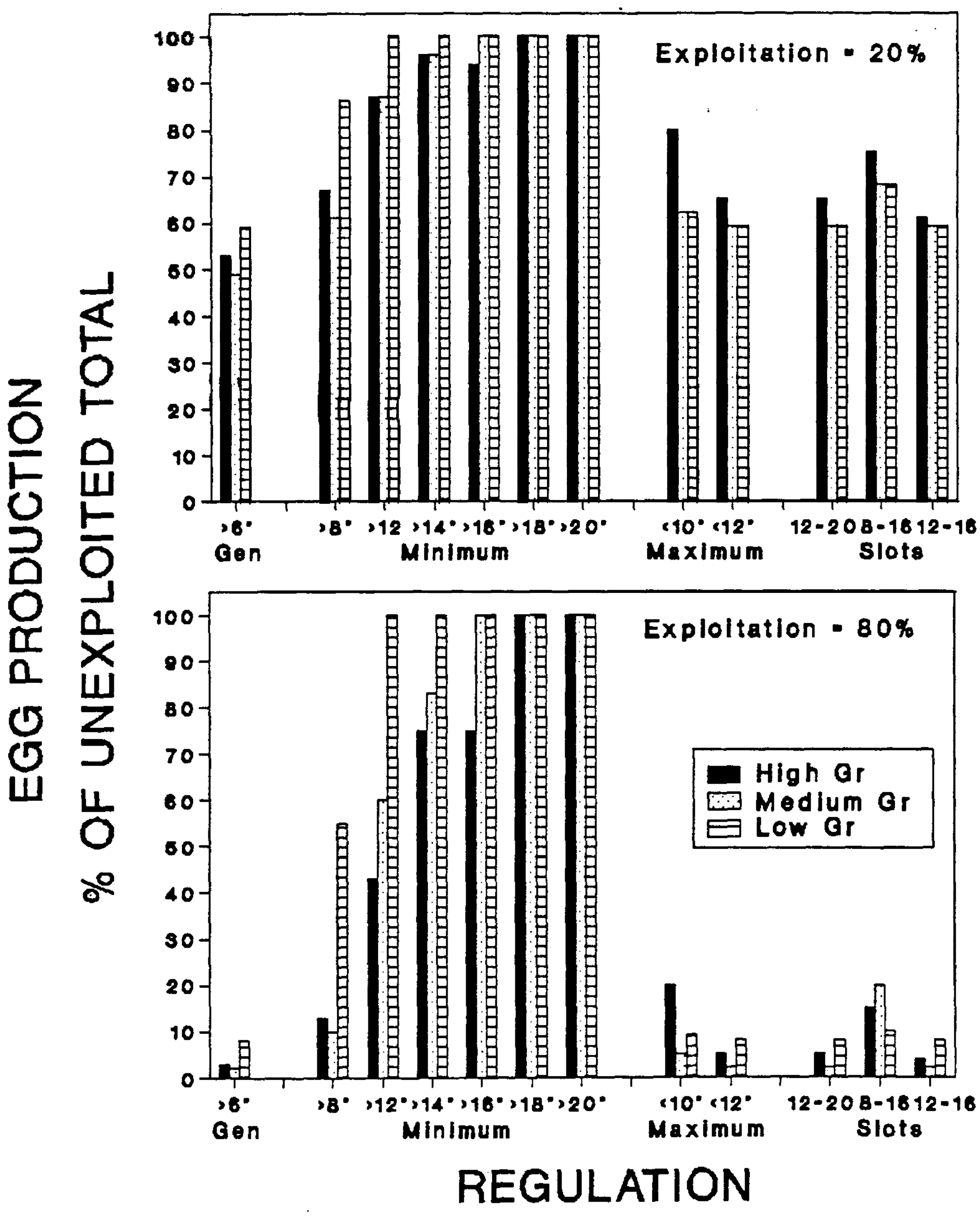


Figure 19. Simulations of egg production (proportion of unexploited number) for populations with varied growth, exploitation, and harvest restrictions. Natural mortality = 0.30 and recruitment constant at 10,000 fish.

Growth rates of rainbow trout were usually greater than those for cutthroat trout. This difference has been explained by the typically less productive northern and central Idaho waters containing westslope cutthroat trout. However, higher rainbow growth may also be dictated by other unknown factors. Rainbow trout growth exceeded that of cutthroat, even at similar conductivities (Figure 4). We had little data where rainbow and cutthroat were found together, making direct comparisons impossible.

Conductivity was a poor predictor of growth in rainbow trout. Much of the variation in rainbow growth may be explained by temperature. For example, nearly all positive outliers on the low end of the conductivity scale came either from spring creeks or tailwater fisheries (Appendix A-1).

Trout densities were significantly correlated with stream width (Figure 6). These results may also be misleading because age 1 and 2 fish were often less vulnerable to electrofishing gear in streams larger than 15 m to 20 m in width. However, they do point out the need to stratify density data when making comparisons on a statewide basis.

Stream width has been inversely related to standing crop in other populations (Binns and Eiserman 1979; Lanka et al. 1987). However, width has explained only a fraction of observed variation (r^2=18-27%) (Lanka et al. 1987). Stream width, by itself, will provide only a crude prediction of densities or standing crops.

Density estimates for 10 m to 50 m wide Idaho streams were highly variable when multiple stations within a stream were sampled (Figure 8). Numerous sampling sites are needed to characterize densities in these streams. The number of sites should be related to habitat variability (Hanken and Reeves 1988). Sampling guidelines might be developed with further analysis of existing data.

There were numerous estimates of angler use for wild trout fisheries in Idaho streams. However, much of the data was expressed in h/km. Comparison of effort on a linear basis should only be done on adjacent or similar stream reaches.

Relatively few Idaho waters had effort estimates expressed in terms of surface area (h/hectare). Estimates for McCoy Creek and Silver Creek were both near 1,000 h/hectare/year and were among the highest observed. Effort on these two streams is well below that reported for other waters nationwide. Dienstadt (1977) reported angler effort estimates in excess of 6,000 h/hectare/year on Hot Creek in California. Estimates of angler use on streams in Colorado can exceed 3,000 (Anderson and Nehring 1984; Nehring, Colorado Division of Wildlife, Fort Collins). Effort estimates for future creel surveys reported as a function of surface area will help with comparisons. Conversions of existing data for references would be a good research priority. This statewide data summary should provide managers with some perspective. We still do not have good predictors, however, of the potential for any single fishery.

Some data needed to compare among fisheries were not collected. Linear rather than area estimates of effort and densities are examples. Weights were rarely reported, precluding the possibility of estimating yields or standing crops. The incorporation of weight into our catch and population data would reduce the masking effects of fish size on densities. Juvenile fish, for example, typically contribute only about 10% of salmonid biomass, but may dominate estimates of total density (Allen 1951). The development of length-weight relationships and conversion of existing data would be a good wild trout research priority.

A core data set focusing on habitat and population variables has been proposed (C. Petrosky, Idaho Department of Fish and Game, personal communication) but has not been used widely for resident fish. Rieman and Apperson (1988) called for standardization of other variables, including fishery statistics. The development of a complete sampling manual should be a priority on this project. Standardization of data collection efforts would provide biologists with easily comparable data on a statewide basis. In a few years, a sizeable gain in information would be realized.

While expanding our in-state database, several other options exist to improve our understanding of wild trout fisheries. A major effort should be made to summarize intermountain data from other states. Platts and McHenry (1988) summarized density and biomass data for trout and char in western streams after subdividing 11 states into 7 "ecoregions." Their density comparisons were confounded by inconsistent treatment of juveniles in population estimates. Biomass estimates are less sensitive to this bias and were available from surrounding states.

Biomass estimates for the Intermountain Sagebrush ecoregion (western Utah, Nevada, southeast Oregon, and southern Idaho) ranged from 1 to 136 kg/hectare and averaged 40 kg/hectare. Thirty-six percent of study sites had standing crop estimates of 15 kg/hectare or less. No estimates of standing crop from Idaho were included.

Estimates for the Columbia River forest ecoregion (central and northern Idaho, eastern Washington, and northeastern Oregon) ranged from 0.5 to 218 kg/hectare and averaged 3.8 kg/hectare. Forty-four percent of study sites had standing crop estimates of 10 kg/hectare or less. The few biomass estimates reported for Idaho waters were included in this summary.

Existing predictive models might also be used. We did not use available habitat models to predict salmonid standing crops in the first year of our project. Several empirical models exist, but are typically limited by small sample sizes, failure to address measurement errors or other statistical problems (Marcus et al. 1990; Fausch et al. 1988). The major biological assumption of these models, that the fish populations are limited by habitat rather than fishing mortality, is often not addressed (Fausch et al. 1990). Also, the time required to learn and measure variables used in more precise models (e.g. Binns and Eiserman 1979) seems prohibitive for most situations.

Despite these limitations, an effort should be made to identify the best of these models for management. We will focus on the simplest models that still provide reasonable predictive precision. In most cases, this will include models with geomorphic variables (Parsons et al. 1981; Lanka et al. 1987).

Fishery biologists are expected to develop realistic management plans for numerous wild trout species in a variety of habitats. The potential for a fishery should be central to any management goal. Additional efforts will continue to be made to provide prediction and perspective on wild trout potential in Idaho waters on this project.

Potential Stock Structures

Growth and natural mortality both had large effects on simulated size structures (Figures 14 and 15). Estimates of growth are relatively easy to obtain and are available for numerous Idaho waters. Estimates of natural mortality are limited, require substantial time and effort to obtain, and are often of questionable accuracy (Vetter 1988). Therefore, goals based on stock structure must be general.

Preferably, results should agree with actual observations. There was poor agreement between our model predictions and empirical observations in several instances (Table 4).

Several factors may have contributed to these differences. The MOCPOP model has some limitations in handling fish lengths. The model assumes all fish in an age class are the same length. This, in part, may explain the sharp inflections in the curves at various points. While this limitation may have some effect on QSD estimates at certain points, the overall shape of the curves are probably reasonable. We also assumed mortality was constant for all age groups in the populations. Assuming constant mortality for all age classes in models may be inappropriate (Vetter 1988). Since we were developing a general model for various populations, we made that assumption. We also assumed that fish would not live past age 6 in the populations. Few older individuals are reported in data for catch-and-release waters.

Differences may also have been due to the accuracy of the empirical data. On the catch-and-release segment of Silver Creek, observed QSD was 2 to 3 times greater than the predicted value (Table 4). However, electrofishing data in this study was not properly corrected for size selection (Cooper and Lagler 1956; McFadden 1961; Thurow 1990). The empirical stock structure we derived from their report data is probably an overestimate. The observed QSD for the Henrys Fork (0.26) was not corrected for selectivity, and probably overestimated as well. Variation in year-class strength could also bias stock structure estimates, particularly when only one year of data is used.

Electrofishing data on the Big Wood was corrected for size selection (Thurow 1990), and our predicted values were still two to three times greater than the empirical estimate of 4% (Table 4). Estimated natural mortality for the Big Wood (0.59) was outside our assumed range of 0.3 to 0.5 (Figure 10). Use of the original growth rate (length at age 4=364) and a higher natural mortality rate of 0.60 results in a model prediction of about 5%, much closer to the observation (Figure 14). Estimated natural mortality for the Henrys Fork special regulation area (X=0.60) (Angradi and Contour 1989) was also above our assumed range.

Waters such as the South Fork Boise River, Little Wood River, and the Big Wood River have been identified as trophy in the Five-Year Plan (Horton et al. 1990). These waters, and other similar ones, may not produce fast enough growth to achieve the 20% target regardless of regulation. For waters managed by catch-and-release, this may not present a problem other than confusing angler expectations. On waters with less restrictive regulations, we may receive pressure to implement more restriction in hopes of achieving the Five-Year Plan target, even though it is unattainable.

Both the observed and predicted size structures have limitations. More empirical data for comparisons may be available from other states, including Montana and Colorado. Both of these states have corrected their electrofishing data for size selection. Effects of variable year-class strength could also be minimized since they have a number of waters with four to eight years of data. We will request size structure data and growth from these states. Estimates of conditional natural mortality by species should also be summarized for out-of-state waters. It is possible that ranges used in future modeling (0.3 to 0.5) could be refined for various species.

Regulation Comparisons

Based on Idaho growth rates, the modeling results suggest that several regulations could be combined for similar responses on most waters. Minimum size limits of 16, 18, and 20 inches all had similar effects for both relative numbers of fish and egg production. To limit the number of comparisons, we did not model the highest growth rates observed in the state (length at age 4 = 430 to 450 mm). Since fish would reach 16 inches in less time, results for those waters may be different. Few streams and rivers in Idaho support these levels of growth, however.

Slot limits and maximum size limits produced little benefit over general regulations, both in terms of egg production and numbers of fish. In practice, slot limits have proven quite effective in producing large fish on a number of Idaho waters (e.g. Henrys Fork, South Fork Boise). These conflicting results imply that slot limits have been effective because of sociological reasons. Anglers do not keep numerous legal fish (high exploitation) below the slot size on these waters. If they did, fishing quality would decline.

The reasons slot limits provide protection for social reasons are that a significant proportion of harvest-oriented anglers may be displaced from these fisheries because of bait or bag restrictions (Lewensky 1986). Few remaining anglers elect to keep small but legal fish. On the South Fork Boise and Henrys Fork rivers, few anglers kept trout despite a lower slot boundary of 305 mm (Rohrer 1984; Reid 1983). Thus, the selection of the actual sizes for the slot appears to be unimportant in most cases. A single slot regulation (e.g. 12 to 16 inches) in conjunction with bag restriction may produce the same fisheries as those used in the recent past (i.e. 8 to 16 inches, 10 to 16 inches, 12 to 16 inches, 12 to 20 inches). If anglers are concerned about the management of trophy fish above 16 inches in size, the implementation of catch-and-release regulations may be more appropriate.

We did not attempt to model the effects of bag limits on a statewide basis. Angler creel habits appear too variable for statewide simulation efforts. Bag limits are usually considered ineffective in reducing harvest, however, because few anglers catch more than one trout (Thurow 1990; Nehring 1985).

The generalized simulation approach provides some insight for regulation simplification. The results are useful for generalized concepts only, however, and should not be used to address water-specific questions. More precise growth estimates and ranges of natural mortality, along with sociological needs, should be used in individual water predictions.

RECOMMENDATIONS

1. Summarize data from other intermountain states and convert existing data to increase our perspective. Data to summarize and convert include:

   - Angler effort (h/hectare) on wild trout waters
   - Standing crops (kg/hectare)
   - Population size structures (PSD's etc.)
   - Natural mortality rates

2. Develop a standardized sampling manual for wild trout fishery and population data. Emphasize reporting consistency. Much of the existing data was collected in an inconsistent manner.

   Yield (kg/hectare)

   - A subsample of weights is the only additional data needed. An estimator of yield should be incorporated into the new departmental creel census program. Existing data can be used by applying length-weight relationships.

   Effort/hectare

   - Much of our data is expressed only in total hours or h/km.

   Standing Crop (kg/hectare)

3. Consider redefining trophy trout (QSD >20%) to reflect biological potential. Few wild trout streams in Idaho have the growth potential to be considered trophy waters as defined in the Five-Year Management Plan (QSD >20%).

4. Adopt one to two slot limits for statewide use. Suggested limits include 8 to 16 inches and 12 to 16 inches. Slot limits may not work in some Idaho waters. If anglers keep legal numbers of small legal trout, large fish numbers would decline.

5. When length at age 4 ranges from 200 to 350 mm, 16-, 18-, and 20-inch minimum size limits will have similar effects on numbers of fish and egg production. Choose a single statewide length limit for these instances.

ACKNOWLEDGMENTS

A host of Department personnel and graduate students contributed to this effort via the completion of past DJ reports. Ted Bjornn and Joel Hunt (University of Idaho) and Wayne Minshall (Idaho State University) contributed conductivity data from a number of streams. Jim Mende and Kurtis Plaster collected conductivity data from waters with missing data. Jon Dudley participated in the statewide summary and analysis.

LITERATURE CITED

Anderson, R.O. 1980. Proportional stock density (PSD) and relative weight (W_r): Interpretive indices for fish populations and communities. Pages 27-33 in S. Gloss, and B. Shupp, editors. Proceedings of the 1st Annual Workshop of the New York Chapter American Fisheries Society, Cazenovia, New York.

Anderson, R. and R.B. Nehring. 1984. Effect of a catch-and-release regulation on a wild trout population in Colorado and its acceptance by anglers. North American Journal of Fisheries Management. 4:257-265.

Angradi, T. and C. Contour. 1989. Henrys Fork fisheries investigations. Idaho Department of Fish and Game, Job Completion Report, Project F-71-R-12, Boise.

Beamesderfer, R.C. 1988. MOCPOP: A flexible simulator for analysis of age-structured populations and stock-related functions. Oregon Department of Fish and Wildlife, Fish Division, Information Reports Number 88-3, Eugene, Oregon.

Bennett, D.H. and T.J. Underwood. 1987. Population dynamics and factors affecting rainbow trout _Salmo_ _gairdneri_ in the Spokane River, Idaho. University of Idaho, Forest, Wildlife and Range Experiment Station, Completion Report No. 3, Moscow, Idaho.

Binns, N.A. and F.M. Eiserman. 1979. Quantification of fluvial habitat in Wyoming. Transactions of the American Fisheries Society. 108:215-228.

Brostrom, J. 1987. River and stream investigations: Henrys Fork fisheries investigations. Idaho Department of Fish and Game, Job Completion Report, Project F-73-R-8, Boise.

Brostrom, J. and R. Spateholts. 1985. River and stream investigations: Henrys Fork fisheries investigations. Idaho Department of Fish and Game, Job Performance Report, Project F-73-R-7, Boise.

Cooper, G.P. and K.F. Lagler. 1956. Appraisal of methods of fish population study-Part III. The measurement of fish population size. Transactions North American Wildlife Conference. 21:281-297.

Corsi, C.E., B. Spateholts, V.K. Moore, and T. Williams. 1986. Regional fishery management investigations: Stream investigations. Idaho Department of Fish and Game, Job Performance Report, Project F-73-R-8, Boise.

Corsi, C. and S. Elle. 1989. Regional fisheries management investigations: Region 6 (Idaho Falls) rivers and streams investigations. Idaho Department of Fish and Game, Job Performance Report, Project F-71-R-12, Boise.

Corsi, C. and S. Elle. 1989. Regional fisheries management investigations: Region 6 (Idaho Falls) rivers and streams investigations -- Big Lost and Little Lost Rivers and Birch and Medicine Lodge Creeks survey. Idaho Department of Fish and Game, Job Performance Report, Project F-71-R-12, Boise.

Deinstadt, J.M. 1977. Catch-and-release angling in California's wild trout streams. Pages 119-124 in R.A. Barnhart and T.D. Roelofs, editors. Proceedings of a National Symposium on Catch-and-Release Fishing. Humboldt State University, Arcata, California.

Goodnight, W.H. 1979. River and stream investigations: Moyie River fishery investigations. Idaho Department of Fish and Game, Job Performance Report, Project F-73-R-1, Boise.

Hankin, D.G. and G.H. Reeves. 1988. Estimating total fish abundance and total habitat area in small streams based on visual estimation methods. Canadian Journal of Fisheries and Aquatic Sciences. 45:834-844.

Heimer, J.T. 1980. River and stream investigations: Portneuf River fisheries investigations. Idaho Department of Fish and Game, Job Completion Report, Project F-73-R-2, Boise.

Heimer, J.T., D. Schill, M. Harenda, and T. Ratzlaff. 1987. Regional fisheries management investigations: Rivers and streams investigations. Idaho Department of Fish and Game, Job Performance Report, Project F-71-R-11, Boise.

Horner, N.J. and B.E. Rieman. 1985. Regional fishery management investigations: River and stream investigations. Idaho Department of Fish and Game, Job Performance Report, Project F-71-R-9, Boise.

Hunt, R.L. 1970. A compendium of research on angling regulations for brook trout conducted at Lawrence Creek, Wisconsin. Wisconsin Department of Natural Resources, Research Report 54, Madison.

Jeppson, P.W. 1981. River and stream investigations: Teton River fisheries investigations. Idaho Department of Fish and Game, Job Completion Report, Project F-73-R-3, Boise.

Lanka, R.P. and W.A. Hubert. 1987. Relations of geomorphology to stream habitat and trout standing stock in small rocky mountain streams. Transactions of the American Fisheries Society. 116:21-28.

Lewynsky, V.A. and T.C. Bjornn. 1983. River and stream investigations: Coeur d'Alene River fisheries investigations. Idaho Department of Fish and Game, Job Completion Report, Project F-73-R-4, Boise.

Lukens, J.R. 1988. Rivers and streams investigations: Snake River game fish populations, fishing pressure and harvest, American Falls Reservoir to South Fork. Idaho Department of Fish and Game, Job Completion Report, Project F-73-R-10, Boise.

Mate, S.M. 1977. River and stream investigations: South Fork Boise River fisheries investigations. Idaho Department of Fish and Game, Job Performance Report, Project F-66-R-2, Boise.

McFadden, J.T. 1961.A population study of the brook trout Salvelinus fontinalis. Wildlife Monographs. 7:1-73.

McFadden, J.T. and E.L. Cooper. 1962. An ecological comparison of six populations of brown trout Salmo trutta. Transactions of the American Fisheries Society. 91(1):53-62.

Mende, J. 1989. Portneuf River assessment. Idaho Department of Fish and Game, Job Completion Report, Project F-71-R-12, Boise.

Moore, V.K. and D. Schill. 1984. River and stream investigations: South Fork Snake River fisheries investigations. Idaho Department of Fish and Game, Job Completion Report, Project F-73-R-5, Boise.

Moore, V.K., D.R. Cadwallader, and S.M. Mate. 1979. South Fork Boise River creel census and fish population studies. Idaho Department of Fish and Game, Annual Report to United States Bureau of Reclamation, Boise.

O'Conner, J.F. and G. Power. 1976. Production by Brook trout in four streams in the Matemek watershed, Quebec. Journal of the Fisheries Research Board of Canada. 33:6-18.

Parkinson, E.A., Berkowitz, J., and C.J. Bull. 1988. Sample size requirements for detecting changes in some fisheries statistics from small trout lakes. North American Journal of Fisheries Management. 8:181-190.

Partridge, F.E., C.E. Corsi, and R.J. Bell. 1990. Regional fisheries management investigations: River and stream investigations. Idaho Department of Fish and Game, Job Performance Report, Project F-71-R-13, Boise.

Platts, W.S. and M.L. McHenry. 1988. Density and biomass of trout and char in western streams. USDA, Forest Service, Intermountain Research Station, General Technical Report INT-241, Ogden, Utah.

Reid, W.W. 1980. North Fork Payette River fisheries investigations. Idaho Department of Fish and Game, Job Completion Report, Boise.

Reid, W.W. 1983. River and stream investigations: South Fork Boise River flow and regulations evaluations. Idaho Department of Fish and Game, Job Performance Report, Project F-73-R-5, Boise.

Reid, W. and B. Mabbot. 1987. Regional fisheries management investigations: River and stream investigations. Idaho Department of Fish and Game, Job Performance Report, Project F-71-R-11, Boise.

Riehle, M.D., B.D. Parker, and J.S. Griffith. 1989. Silver Creek fisheries evaluation. Idaho Department of Fish and Game, Final Report, Project F-71-R-12, Boise.

Rieman, B.E., and K.A. Apperson. 1989. Status and analysis of salmonid fisheries: Westslope cutthroat trout synopsis and analysis of fishery information. Idaho Department of Fish and Game, Project F-73-R-11, Boise.

Rohrer, R.L. 1989. Lake and reservoir investigations: Boise River reservoirs. Idaho Department of Fish and Game, Job Performance Report, Project F-73-R-11, Boise.

Rohrer, R.L. 1990. River and stream investigations: Upper Boise River Basin fisheries investigations. Idaho Department of Fish and Game, Job Performance Report, Project F-73-R-12, Boise.

Scarneccia, D.L. and E.P. Bergersen. 1987. Trout production and standing crops in Colorado's small streams, as related to environmental features. North American Journal of Fisheries Management. 7:315-330.

Schill, D.J. and J. Heimer. 1988. Regional fisheries management investigations: Rivers and streams investigations. Idaho Department of Fish and Game, Job Performance Report, Project F-71-R-12, Boise.

Schill, D.J. and J.J. Mende. 1990. Regional fisheries management investigations: Region 5 lowland lakes and reservoirs investigations. Idaho Department of Fish and Game, Job Performance Report, Project F-71-R-14, Boise.

Spateholts, R. and V. Moore. 1985. River and stream investigations: Henrys Fork fisheries investigations. Idaho Department of Fish and Game, Job Performance Report, Project F-73-R-6, Boise.

Thurow, R. 1983. River and stream investigations: Middle Fork Salmon River fisheries investigations. Idaho Department of Fish and Game, Job Performance Report, Project F-73-R-5, Boise.

Thurow, R. 1987. River and stream investigations: Wood River fisheries investigations. Idaho Department of Fish and Game, Job Performance Report, Project F-73-R-9, Boise.

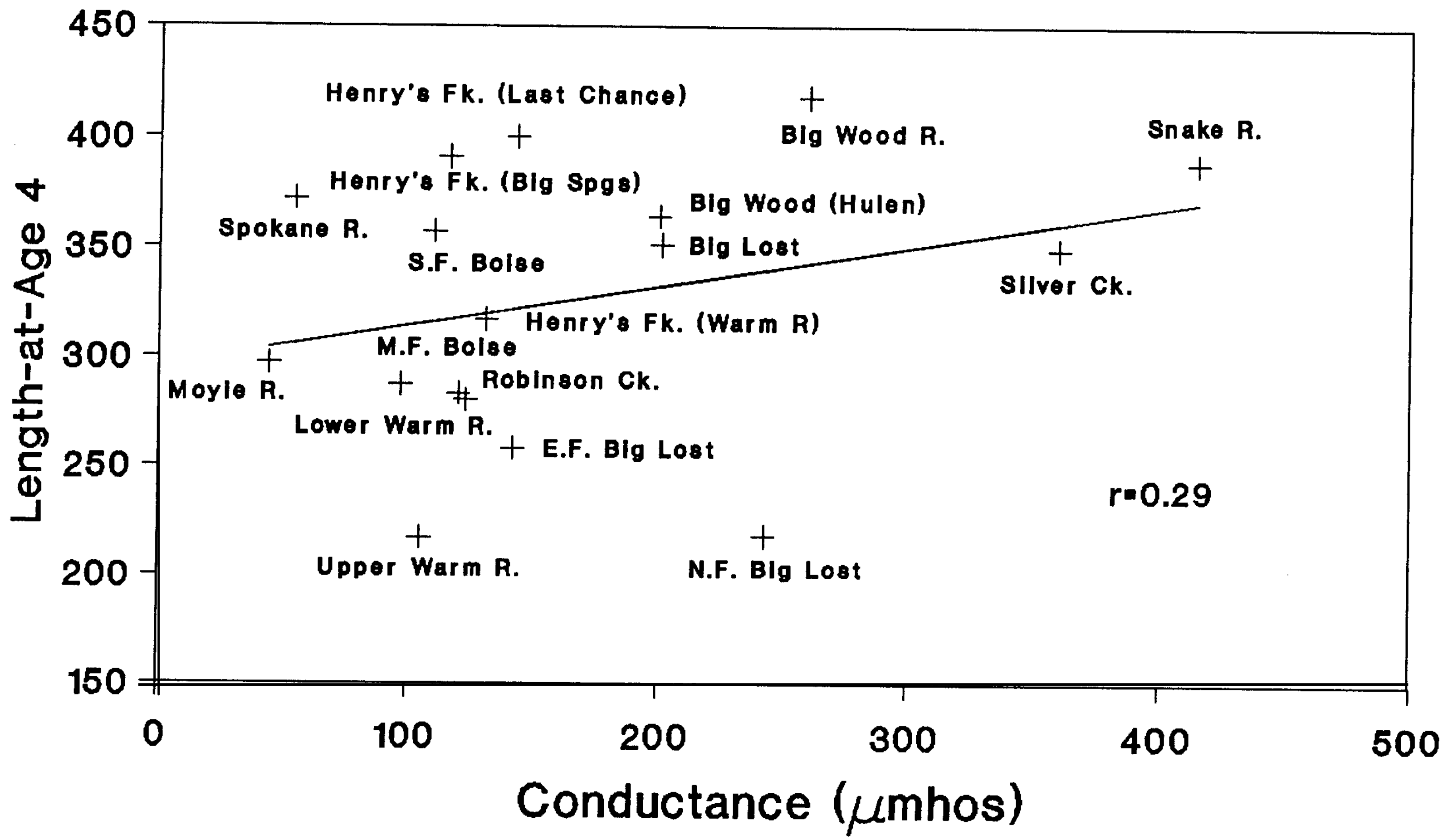
Thurow, R. 1988. River and stream investigations: Wood River fisheries investigations. Idaho Department of Fish and Game, Job Performance Report, Project F-73-R-10, Boise.

Thurow, R. 1990. River and stream investigations: Wood River fisheries investigations. Idaho Department of Fish and Game, Job Completion Report, Project F-73-R-12, Boise.

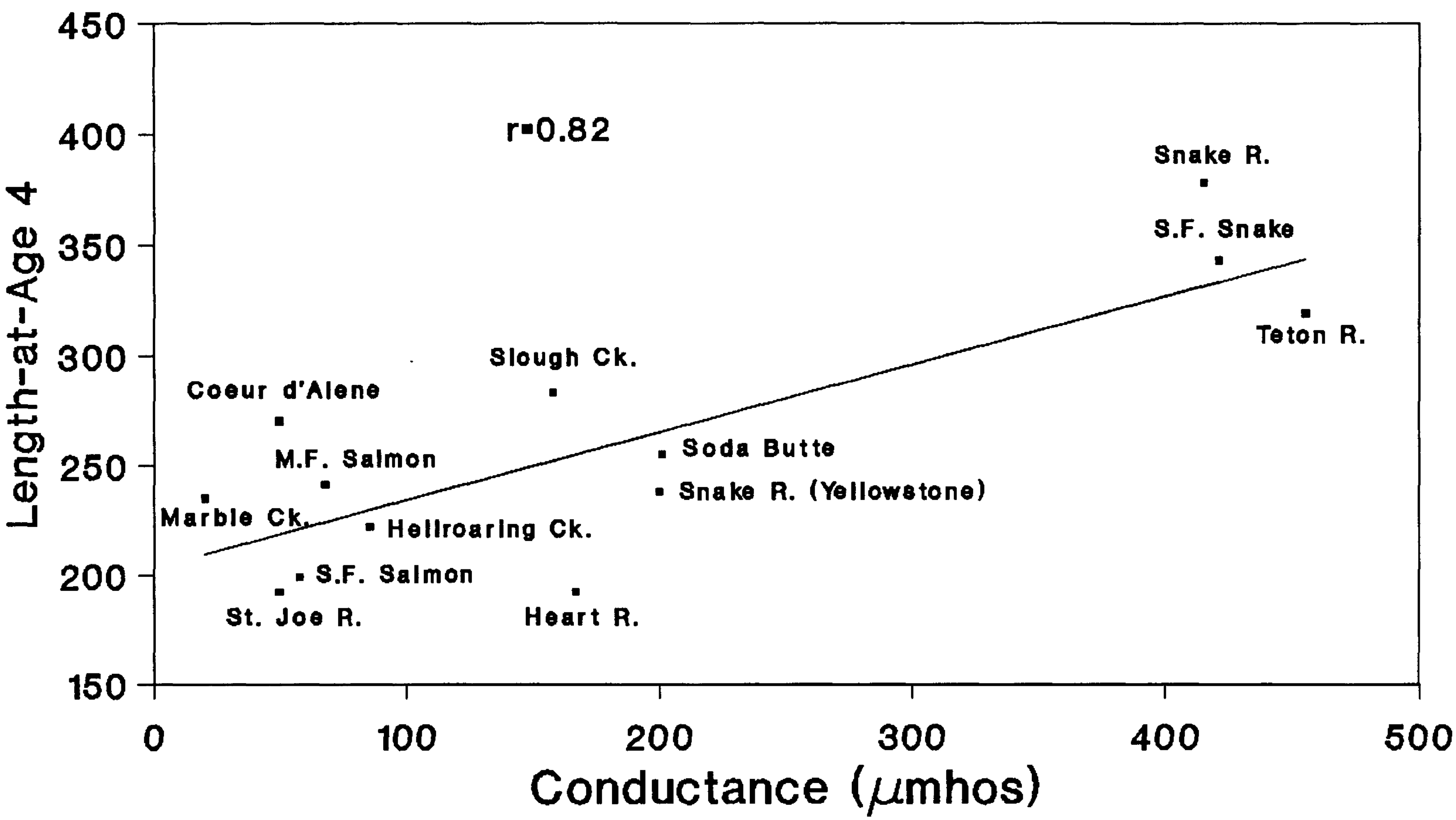
Thurow, R., L. Wishard, W. Christensen, and P. Aebersold. 1981. River and stream investigations: Blackfoot River fisheries investigations. Idaho Department of Fish and Game, Job Completion Report, Project F-73-R-3, Boise.

Zar, J.H.1974. Biostatistical analysis. Prentice-Hall, Inc. Englewood Cliffs, New Jersey.

A P P E N D I C E S



Appendix A-1. Relation of length at age 4 for fluvial rainbow trout vs late summer conductivity in 17 Idaho streams.



Appendix A-2. Relation of length at age 4 for fluvial rainbow trout vs late summer conductivity in 13 Idaho and Yellowstone National Park streams.

Appendix B. Summary of back-calculated lengths at age for fluvial wild trout populations in Idaho[a].

Stream	Region	Species	Length at age I	II	III	IV	V	VI	VII	VIII	Source
Big Lost River	6	RBT	104	185	277	351	424	467	534	559	Corsi and Elle 1989
East Fork Big Lost River	6	RBT	142	185	208	258	349				Corsi and Elle 1989
North Fork Big Lost River	6	RBT	92	142	188	218	248				Corsi and Elle 1989
Sawmill Creek	6	RBT	79	138							Corsi and Elle 1989
Little Lost River	6	RBT	97	171	229	271					Corsi and Elle 1989
Birch Creek	6	RBT	94	153	197	246					Corsi and Elle 1989
Medicine Lodge Creek	6	RBT	108	189	227	283	325				Corsi and Elle 1989
Upper Warm River	6	RBT	107	160	199	217	223				Bostrum and Spateholts 1985
Lower Warm River	6	RBT	108	185	251	283	346	369	399		Bostrum and Spateholts 1985
Robinson Creek	6	RBT	96	145	203	240	299	322	317		Bostrum and Spateholts 1985
Henrys Fork Snake River	6	RBT	146	265	363	434	493	532			Angradi and Contour 1989
Middle Fork Boise River	3	RBT	71	156	227	287	338	380			Rohrer 1989
Spokane River	1	RBT	157	250	323	372	396				Bennett and Underwood 1987
South Fork Boise River	3	RBT	105	193	286	357	414				Moore et al. 1979
Big Wood River	4	RBT	100	176	279	358	461				Thurow 1988
Portneuf River	4	RBT	125	214	292	358	404				Mende 1986
Silver Creek	4	RBT	126	213	294	358	389				Riehle et al. 1989
Twin Bridges Creek	6	RBT	89	132	186	243					Corsi and Elle 1989
Moyie River	1	RBT	98	160	228	297					Horner and Rieman 1985
Snake River	5/6	RBT	105	173	305	388	533				Lukens 1988
Fall River	6	RBT	104	182	252	309					Bostrum 1986
Henrys Fork Warm River	6	RBT	113	191	255	317	349				Bostrum and Spateholts 1985

Appendix B. Continued.

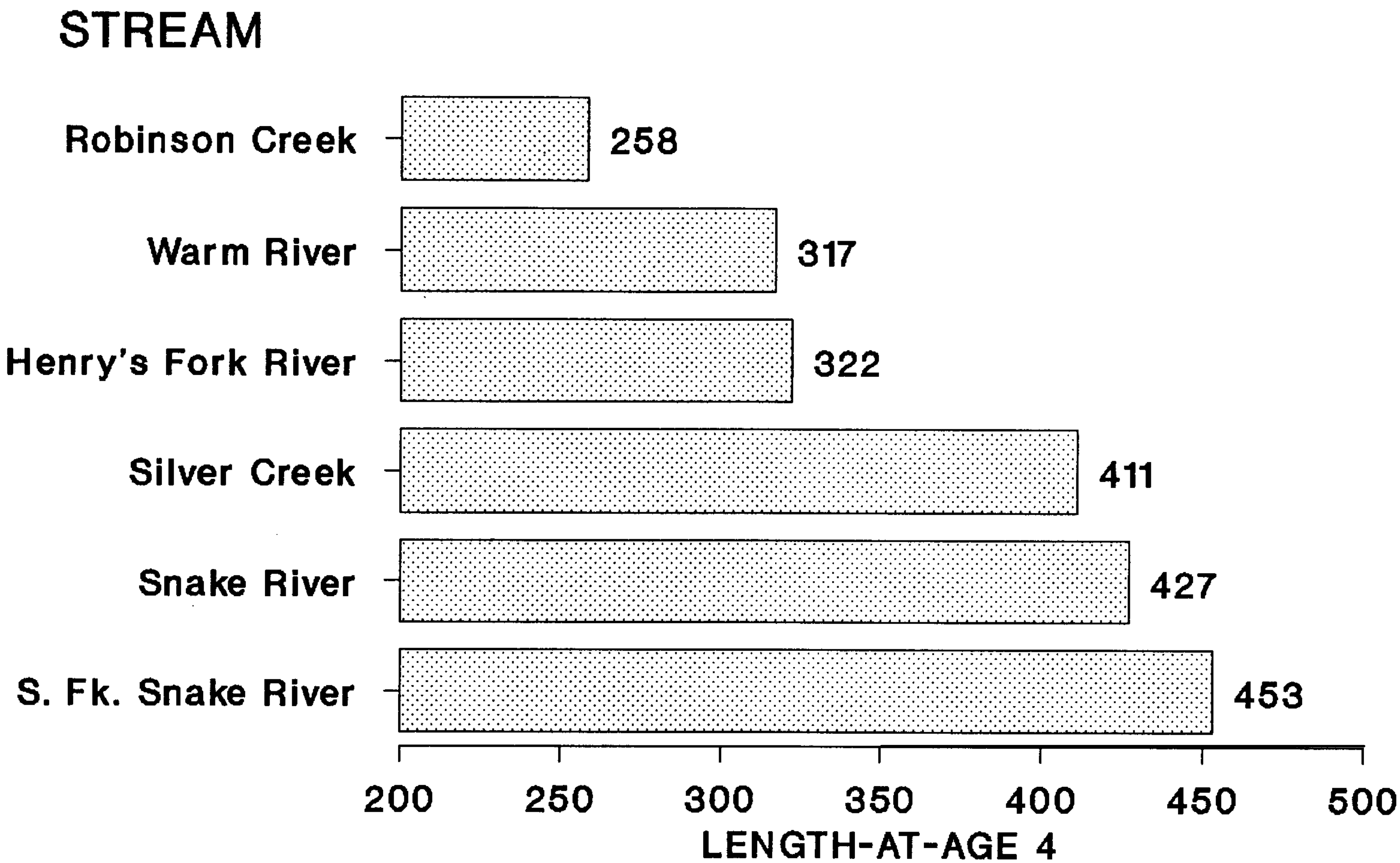
Stream	Region	Species	Length at age I	II	III	IV	V	VI	VII	VIII	Source
South Fork Snake River	6	CT	86	184	277	343	410	450	480		Moore and Schill 1984
Teton River	6	CT	114	179	254	319	368	399			Bostrum in press
Middle Fork Salmon River	6	CT	57	95	165	241	305	352			Mallet 1963
Kelly Creek	2	CT	66	101	153	213	251	306			Johnson and Bjornn 1978
South Fork Salmon River	3	CT	51	92	137	199	244				Thurow 1987
Coeur d'Alene River	1	CT	74	115	175	270	350	420			Rieman 1989
St. Joe River	1	CT	52	91	143	192	243	291			Rieman 1989
Snake River	6	CT	140	234	301	378	449	535			Lukens 1988
Medicine Lodge Creek	6	CT	100	166	217						Corsi and Elle 1989
Marble Creek		CT	50	133	178	235	254				Rieman 1989
South Fork Snake River	6	BRN	97	233	372	453	550	589			Moore and Schill 1984
Warm River	6	BRN	109	171	252	317	372	417	467		Bostrum and Spateholts 1985
Robinson Creek	6	BRN	105	155	214	258	285	287			Bostrum and Spateholts 1985
Henrys Fork Snake River	6	BRN	109	181	256	322	374				Bostrum and Spateholts 1985
Silver Creek	4	BRN	157	228	333	411	472	514	632		Reihle et al. 1989
Snake River	5/6	BRN	129	236	333	427	504	585			Lukens 1988
Lower Big Lost River	6	BRK	164	262	360	401					Corsi and Elle 1989
Starhope Creek	6	BRK	90	141	186						Corsi and Elle 1989
Lake Creek	6	BRK	93	162	205						Corsi and Elie 1989
West Fork Big Lost River	6	BRK	92	142	181	228	367				Corsi and Elle 1989
Summer Creek	6	BRK	99	149	186						Corsi and Elle 1989
North Fork Big Lost River	6	BRK	102	162	216						Corsi and Elle 1989
Little Robinson Creek	6	BRK	84	141	209						Spateholts and Moore 1985

TABLES

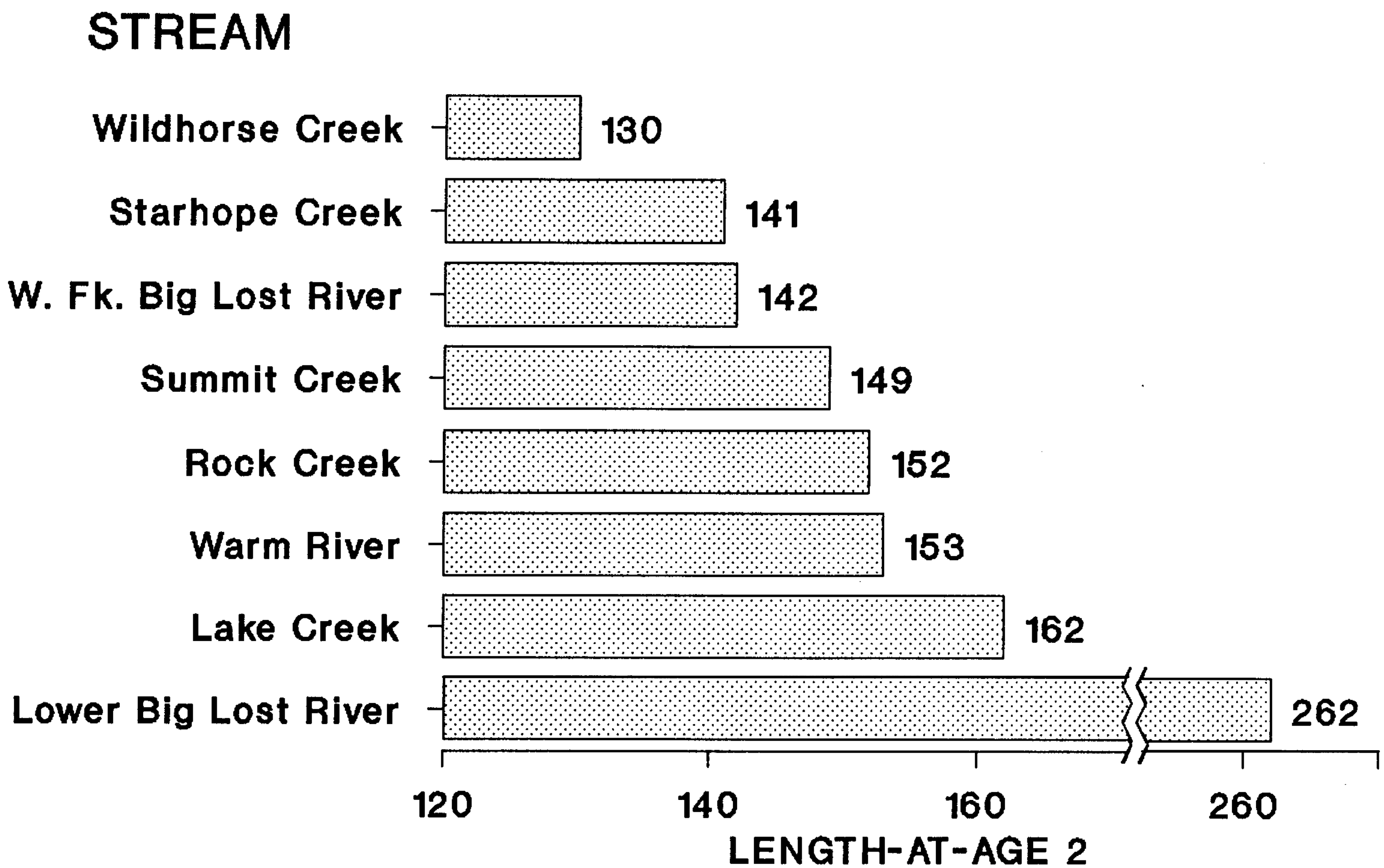
Appendix B. Continued.

Stream	Region	Species	Length at age I	II	III	IV	V	VI	VII	VIII	Source
Snow Creek	6	BRK	70	120	129						Spateholts and Moore 1985
Rock Creek	6	BRK	88	152	144	248					Spateholts and Moore 1985
Beaver Creek	6	BRK	83	158							Spateholts and Moore 1985
Porcupine Creek	6	BRK	99	158	232						Spateholts and Moore 1985
Fish Creek	6	BRK	80	136	169						Spateholts and Moore 1985
Warm River	6	BRK	87	153	189						Spateholts and Moore 1985
Partridge Creek	6	BRK	75	138	193						Spateholts and Moore 1985
Conant Creek	6	BRK	107	177	246						Spateholts and Moore 1985
Squirrel Creek	6	BRK	97	162	217						Spateholts and Moore 1985
Buffalo River	6	BRK	113	160	256						Spateholts and Moore 1985
Chick Creek	6	BRK	79	135							Spateholts and Moore 1985
Little Lost River	6	BUL	99	155	240	314					Corsi and Elie 1989
South Fork Salmon River	3	BUL	91	164	272	403	497	578			Thurow 1987

[a] RBT = rainbow trout
CT = cutthroat trout
BRN = brown trout
BRK = brook trout
BUL = bull trout



Appendix C-1. Back-calculated length at age 4 (mm) for fluvial brown trout in six Idaho streams.



Appendix C-2. Back-calculated length at age 2 (mm) for fluvial brook trout in eight Idaho streams.

Appendix D-1. Summary of effort statistics for stream fisheries in Idaho.

Stream Name and Year	Section and Regulation	Section length	x stream width	Census dates	Effort Total hours	h/ hectare	h/km[a]	Source
Portneuf River 1986	Hwy 30-Kelly Bridge General	25.6 km	-	May 25-Sep 12 1986	10,592	-	(351- x-414	Heimer et al. 1987
Portneuf River 1979	Hwy 30 Bridge to Kelly Road General	25.6 km	-	May 25-Sep 15 1979	16,183	-	x-632	Heimer 1980
South Fork Boise River 1982	Anderson Ranch to Danskin Bridge Special Regs. 3<12, 1>20	15.9 km	-	May 29-Nov 30 1982	13,68	-	853	Reid 1980
South Fork Boise River 1978	Anderson Ranch Dam to Danskin Bridge 3 fish >12 inches	15.9 km	-	May 27-Nov 30 1978	18,651 22,355 w/ winter season	-	1,173 1,406 w/ winter season	Moore et al. 1979
North Fork Payette River 1980	Banks to Smiths Ferry General	37.4 km	-	May 24-Oct 10 1980	3,580	-	96	Reid 1980
South Fork Payette River	Mouth to Alderck Bridge			May 24-Oct 10	3,574	-	-	Reid 1980
Warm River 1984	Hwy 47 to Pineview General	28 km	-	May 26-Sep 2 1984	7,980	-	(106- 5,200) 285	Brostrum Spateholts 1985
Big Wood River 1986 & 1987	Hulen Bridge to N Fork Catch and Release	8.3 km	15 m	May 23-Nov 13	(3,635- 5,881) x=379	(290- 469) x-573	(438- 708)	Thurow 1987
Big Wood River 1986 & 1987	Sections 3,4,6,7,8,9,10 General	29.6 km	18 m	May 23-Nov 15	(20,552- 27,699) x=24,126	(383- 516) x=449	(694- 936) x=815	Thurow 1987

Appendix D-1. Continued,

		Effort						
Stream Name and Year	Section and Regulation	Section length	x stream width	Census dates	Total hours	h/ hectare	h/km[a]	Source
Little Wood River 1986	Sections 1 & 3 General	8.4 km	17.5 m	Jun 15-Nov 15	3,984	300	474	Thurow 1987
Little Wood River 1986	Section 2 - Beartracks Catch and Release	4.4 km	13 m	Jun 14-Nov 15	938	166	213	Thurow 1987
Middle Fork Boise River 1988	Sections 1 & 3 General	31.2 km	27 m	May 28-Oct 28 1988	8,749	(11-102) x=97	(211-347) x=279	Rohrer 1989
South Fork Boise River 1988	Featherville to Big Smoky General	36 km	-	May 28-Oct 14 1988	8,200	-	228	Partridge et al. 1990
Moyie River 1975 & 1978	Eastport to Moyie Springs General	-		Jun 27-Aug 30 1975 Jun 24-Aug 8 1978	75-4.362 78-1,232	- -		Goodnight 1979
Teton River 1980	Mouth to Trail Creek General	175 km	-	May 24-Sep 25	79,511	-	456	Jeppson 1981
Couer d'Alene River 1982	Special Regs. Section General Regs. Section	- -	- -	- -	- -	- -	164 501	Lewynsky & Bjornn 1983
Henrys Lake 1985	Between Ashton Reservoir & Warm River General	-	-	May 25-Nov 8	10,473	-	-	Bostrum 1987
Boise River 1986	Barber Dam to Glenwood General	18.7 km	-	Mar 1,1986-Feb 2, 1987	50,984	-	2,726	Reid and Mabbott 1987
McCoy Creek 1987	Mouth to Spring Creek General	24 km	6.5 m	May 28-Aug 30	17.200	981	637	Elle et al. 1990 in press
Medicine Lodge 1987	Section N/A General	34 km	6.5 m	May 23-Sep 11	3,743	169	110	Corsi & Elle 1989

Appendix D-1. Continued,

Stream Name and Year	Section and Regulation	Effort: Section length	x stream width	Census dates	Total hours	h/ hectare	h/km[a]	Source
Birch Creek 1982	Reno Ditch to above Kaufman Guard Station General	29.1 km	-	-	23,426	-	805	Corsi et al. 1983
South Fork Snake River 1979	Heise to Palisades Dam General	64.4 km	-	Apr 3-Sep 17	64,355	-	998	Moore and Schill 1984
Snake River 1987	American Falls to Idaho Falls General	60.7 km	-	Jun 2-Nov 2	34,086	51	561	Lukens 1988
Silver Creek 1987	Nature Conservency Catch and Release	-	30 m	May 23-Nov 29	-	350	-	Reihle et al. 1989
South Fork Boise River 1978	Anderson Dam to Danskin Bridge Special	15.9 km	-	May 27-Nov 30	18,647	-	1,173	Moore et al. 1979
Henrys Fork 1987	Pinehaven to Hatch Ford General	7 km	-	May 23-Sep 7	11,712	-	1,039	Angradi and Contour 1989

[a]Parenthesis ( ) indicate range if more than one stream segment available.

Appendix D-2. Summary of harvest statistics for stream fisheries in Idaho.

Stream Name and Year	Section and Regulation	Total fish	Harvest /km	Harvest /hectare	Harvest: x length	x weight	N	% >300	% >400	% >500	Catch Rate: C	H
Portneuf River 1986	Hwy 30-Kelly Bridge General	1,274	(42-56) 50	-	CT[b]=278 RB=288 Total=281	- -	363 203 566	44 36 36	5 11 7	0 0 0	N/A	CT=.08 RB=.04 Total=0.12
Portneuf River 1979	Hwy 30-Kelly Bridge General	3,757	147	-	-	-	-	-	-	-	N/A	CT=.06 RB=.17 Total=.23
South Fork Boise River 1982	Dam to Danskin 3 <12 & 1 >20	688	42	-	-	-	-	-	-	-	RB=1.40 BT=.004 Total=1.4	RB=.05 Total=.05
South Fork Boise River 1980	Dam to Danskin Bridge 3 > 12 inches	RB=1,677 BT=22 Total=1,699	107	-	381	-	-	-	-	-	RB=1.64 BT=.0002 Total=1.64	Total=.09
North Fork Payette River 1980	Banks to Smith Ferry General	RB=778	21	-	-	-	-	-	-	-	N/A	RB=.22 Total=.22
South Fork Payette River 1988	Mouth to Alden Creek Creek Bridge General	RB=1,328 BK=11 Total=1,339	-	-	-	-	-	-	-	-	N/A	RB=.37 BK=.00 Total=.37
Warm River 1984	Hwy 47-Pineview General	2,096	-	-	RB=242 BN=347	-	-	-	-	-	N/A	Total=.27
Big Wood River 1987	Hulen Bridge to North Fork Catch-and-Release	0	0	0	0	-	-	-	-	-	1.95	-
Big Wood River 1987	All remaining river sections General	RB=6,957 BK=193 Total=7,150	104/km	-	BK=- RB=299 Total=299	-	-	-	-	-	1.18 includes hatchery fish	0.42
Middle Fork Boise River 1988	Willow Creek to Alexander Creek General	RB=1,231 BT=240 Total=1,471	RB=38.4 BT=7.7 Total=47.2	RB=15 BT=3 Total=18	RB=251 BT=300 x=256	177	-	-	-	-	0.70 includes hatchery	RB=0.1 BT=0.0 Total=0.1

Appendix D-2. Continued.

Stream Name and Year	Section and Regulation	Harvest: Total fish	Harvest /km	Harvest /hectare	x length	x weight	N	% >300	% >400	% >500	Catch Rate: C	Catch Rate: H
South Fork Boise River 1988	Featherville to Big Smokey Creek General	RB=807 BT=109 KO=66 Total=982	27	-	RB=328 BT=318 KO=284 Total=300	-	-	-	-	-	0.95 includes wild fish and hatchery fish	RB=0.1021 BT=0.01 KO=0.01 Total=0.12
Teton River 1980	Entire stream (175 km) General	30,919	177	-	RB=273 CT=323 BK=229 Total=289	-	-	-	-	-	-	BK=.08 RB=.13 CT=.15 HRB=.04 Total=0.39
Henrys Fork 1985	Ashton Reservoir to Warm River General	2,099	-	-	-	-	-	-	-	-	-	RB=.17 BN=0.02 Other=.01 Total=0.20
Boise River 1986	Glenwood Bridge to Barber Dam General	2,706	144	-	-	-	-	-	-	-	-	RB=0.05 BN=0.01 Total=0.05

[a]Stream and date corespond to source in E-1.
[b]CT=cutthroat trout
RB=rainbow trout
BN=brown trout
BK=brook trout
BT=bull trout
KO=kokanee

JOB PERFORMANCE REPORT

State of: Idaho

Name: River and Stream Investigations

Project No: F-73-R-13,

Title: Bull Trout Aging and Enumeration Comparisons

Subproject No.: II

Job No.: 2

Study No.: IV

Period covered: March 1, 1990 to March 31, 1991

ABSTRACT

We conducted a pilot study comparing bull trout ages derived from scales and otoliths. Five research biologists aged both structures from 12 individual fish for a total of 120 age estimates. Otoliths consistently yielded older ages for individual fish than scales. Otolith estimates proved to be more precise, even though study participants were more familiar with the scale reading process. We recommend that an expanded study be conducted. Until then, ages derived from scale analysis should be used with caution.

We compared three methods for estimating bull trout densities and size structure. We worked in a single stream. Methods were day snorkeling, night snorkeling, and electrofishing. We observed no statistical differences in densities among the three sampling techniques. These results conflict with past research in Montana and Oregon. Precision of snorkeling estimates was similar to electrofishing. Snorkeling provided size structures comparable to electrofishing. Temperature fluctuations between 7.5°C and 13°C had no consistent effect on observed bull trout densities. Bull trout juveniles were not observed in the water column at 2°C. We did observe several individuals at this temperature by moving cobble and rubble.

Author:

Dan Schill
Senior Fishery Research Biologist

90REPRT

INTRODUCTION

The bull trout Salvelinus confluentesis the least studied native salmonid in Idaho. The ability of this species to grow to large sizes in unproductive systems provides a unique fisheries opportunity. Concern regarding the status of the species has prompted interest in bull trout life history and habitat requirements.

There have been a few bull trout aging studies in Idaho (Pratt 1985; Irving 1986; Thurow 1987; Corsi and Elie 1989). All used scale analysis. Recent work has questioned the accuracy of aging studies (Beamish and McFarlane 1983). Scale analysis is unreliable in aging lake trout Salvelinus namycush and arctic char Salvelinus alpinus (Sharp and Bernard 1988; Beamish 1973; Power 1978). Low estimates of age from scales result from loss of annuli due to abrasion (Alvord 1954) or from low mineral deposition in slow-growing fish (Johnson 1976). Bull trout prefer colder water than other salmonids, and growth is typically slow (Fraley et al. 1981; Goetz 1989). Preliminary results of scale/otolith comparisons from Flathead Lake show less than 50% agreement (L. Hanzel, Montana Department of Fish, Wildlife, and Parks, personal communication). Management strategies often depend on estimates of age structure (Barber and McFarlane 1987), but reliable aging data may not yet be available for bull trout.

Fluvial bull trout habitat is often typified by cold water and low conductivity. Fish are found in association with bottom cover and woody debris (Goetz 1989; Pratt 1984; Shepard et al. 1982). These characteristics can create sampling problems for common enumeration techniques like electrofishing and snorkeling counts.

Size of electrofishing fields is directly related to conductivity. Substrate also affects the electrofishing field (J. Reynolds, University of Alaska, personal communication). Surprising numbers of bull trout have been located within the substrate by snorkeling after successive removal passes with electrofishing gear (Fraley et al. 1982). Nonetheless, in the Flathead River system, electrofishing estimates typically exceeded those of snorkeling.

Goetz (1990) recently reported that night snorkeling estimates for age 1 and 2 bull trout ($0.08/m^2$) exceeded estimates from electrofishing ($0.05/m^2$) and day snorkeling ($0.02/m^c$). Goetz suggested that night snorkeling was superior to day snorkeling, and further stated that day snorkeling may require intense sampling just to document juvenile presence. Goetz also suggested that, at night, juvenile bull trout are often clumped together in groups and are further from cover.

Many Idaho bull trout populations are located in wilderness areas or waters where electrofishing is ineffective. Snorkeling will likely be the only method **available** to estimate bull trout abundance in these areas. More active inventory and management of the species is likely to occur in the near future. Differences in the various techniques need to be quantified and to develop appropriate correction factors.

OBJECTIVES

1. To compare estimates of bull trout age derived from otoliths and scales.

2. To compare the precision of aging estimates derived from scales and otoliths.

3. To compare three techniques of density estimation for bull trout.

4. Compare day and night habitat use of fluvial bull trout.

STUDY SITE

We selected Profile Creek, a tributary to the East Fork of the South Fork Salmon River, for population estimate comparisons. Past work indicated relatively high densities of bull trout (Thurow 1987). Habitat within the sites include boulders, large cobble, and some woody debris. Water temperatures were low, ranging from 7.8 to 13.3°C during the August sampling period. Stream flow during late fall was 0.4 m^3/s.

A total of six stations were used in our comparisons. Mean widths of all stations was 5.2 m. Physical parameters of the study segments are presented in Table 1.

METHODS

Aging Comparisons

We compared bull trout age estimates from otoliths and scales. We were limited by the number of otolith samples available, so our study is preliminary. Twelve paired samples (scales and otoliths) were collected during 1989 and 1990. The samples were from three fisheries, including Lake Pend Oreille, Dworshak Reservoir, and the South Fork of the Salmon River.

Scales were pressed on acetate slides and read on a microfiche projector. Otoliths were read using a dissecting microscope and either surface light or reflected light. Total age was estimated by each observer.

Five biologists were involved in the study. Following an initial discussion of aging criteria for both techniques, each individual read both structures from the 12 fish. Structures were not paired, so readers could not associate the scale and otolith for any individual. Participants had no knowledge of fish lengths.

We compared the mean age for individual fish derived by each structure. We compared precision of each technique with standard errors for individual fish.

Table 1. Physical dimensions of bull trout sampling stations on Profile Creek, tributary to East Fork South Fork Salmon River, August 1990.

Station	Lenqth (m)	x width (m)	No. habitat units[a]
1	157	4.7	16
2	152	5.6	17
3	88	4.7	
4	124	5.3	
5	174	5.0	21
6	143	5.2	16
Total	843	5.0	70

[a] As defined by Bisson et al. (1982).

VTABS

Enumeration Comparisons

All enumeration work was a joint effort with United States Forest Service (USFS) Intermountain Research Station personnel. We began work at each of six stations by placing block nets at the upstream and downstream boundaries. Habitat within four stations was classified as pools, runs, riffles, or pocketwater as in Bisson et al. (1982). Borders between each habitat type were flagged with surveyors tape.

For all snorkel counts, a single diver moved upstream against the current and counted age 1+ bull trout present within each habitat unit. We made no attempt to enumerate fry because of previously documented problems counting fry with snorkeling techniques (Griffith 1978). Fish were counted only after the diver moved upstream past them. Bull trout size was classified by 100 mm length groups.

Within Stations One, Two, Five, and Six, we conducted three replicate snorkel counts approximately one hour apart. Replicates within individual sites were all conducted by the same observer.

Snorkeling techniques were the same for both the day and night counts. We conducted day counts between 1000 and 1600 hours to ensure adequate lighting. Night counts were conducted between 2300 and 0500 hours with the aid of an underwater light.

At Stations One and Two, block nets were held in place for electrofishing on the following day. For the upper four stations, block nets were removed after snorkeling and reinstalled during the following week. Electrofishing of the upper four stations occurred approximately one week after snorkeling took place.

We conducted depletion type population estimates at each site using backpack electrofishing gear. Two units were needed to adequately cover the stream. A minimum of two passes were made at each site. We used a two-pass estimate (LeCren 1967) on Stations Two and Three where catches declined by 75% or more between successive catches. We needed three passes on Station One and four passes on Stations Five and Six to obtain estimates.

Electrofishing estimates and confidence limits were calculated by the MicroFish software program (Van Deventer and Platts 1989). We calculated confidence limits around mean replicate snorkel counts for four stations using the formula 2 X SD/n. Coefficients of variation were calculated from the replicate snorkel counts and the electrofishing data to compare relative precision of the techniques. We compared estimates of density obtained with the three methods using ANOVA procedures with sample site as a blocking variable.

We recorded total lengths from all bull trout sampled during electrofishing. We generated a length frequency for all fish collected from the stream. We also grouped electrofishing captures in the same length categories listed above for snorkeling estimates to compare between the techniques.

Following the electrofishing, we estimated areas of individual habitat units within Stations One, Two, Five, and Six. Only mean widths and total length were recorded for Stations Four and Five. Temperature was recorded during all sampling periods using a continuous recording thermograph. Conductivity corrected to 25°C was measured using a portable probe.

RESULTS

Aging Comparisons

Mean ages were consistently greater from otoliths than scales. The mean estimate from scales exceeded that of otoliths only once (Figure 1). Differences in mean age were often greater than one year and, in one instance, approached 3 years.

Only one of five participants had experience reading otoliths. Estimates of age derived with scales proved, however, to be less precise for most fish (Figure 2).

Enumeration Comparisons

We found no consistent differences in bull trout densities between day and nighttime snorkel counts. Night counts exceeded day counts in Stations One and Six, while the opposite was true in Stations Two and Five (Figure 3). The differences were not diver-related, as Stations One and **Six** were counted by different divers. Results did not appear related to habitat, which was similar in Stations One and Two and Five and Six.

Densities were variable among sites, regardless of the technique used. Electrofishing techniques yielded slightly higher density estimates for age 1+ fish at all stations than either snorkeling method (Figure 4). We found significant differences in densities between the three techniques when using only the initial replicate snorkel count (p(0.01) or when using means of available replicate counts ($p<0.02$). Linear contrasts showed significant differences were between electrofishing either of the snorkeling techniques ($p<0.01$ and p(0.01). No differences were observed between the two snorkeling techniques ($p>0.66$).

Precision of estimates was good in most stations regardless of technique used. Coefficients of variation were less than 8% in 9 of 12 estimates (Table 2). Electrofishing in Station One resulted in the least precise estimate (coefficient of variation = 27%). In all cases, confidence limits for electrofishing were truncated because the actual number of fish collected exceeded the calculated lower bound.

The three techniques yielded similar estimates of size structure for the Profile Creek population (Figure 5). Size structure differences between electrofishing and snorkeling counts were greater for individual stations than with the pooled data.

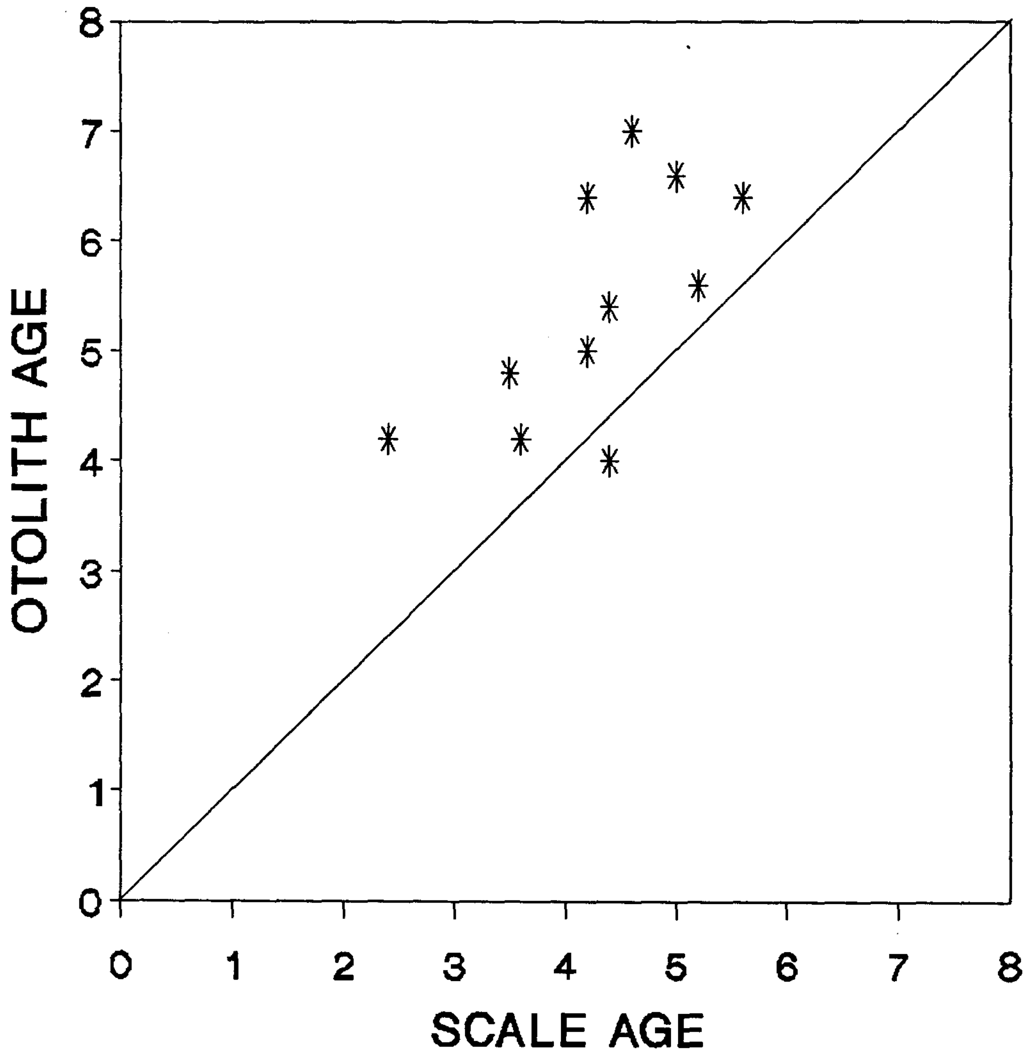


Figure 1. Mean estimates (5 replicates) of age for 12 bull trout derived by biologists reading the same two structures. The line would represent perfect agreement.

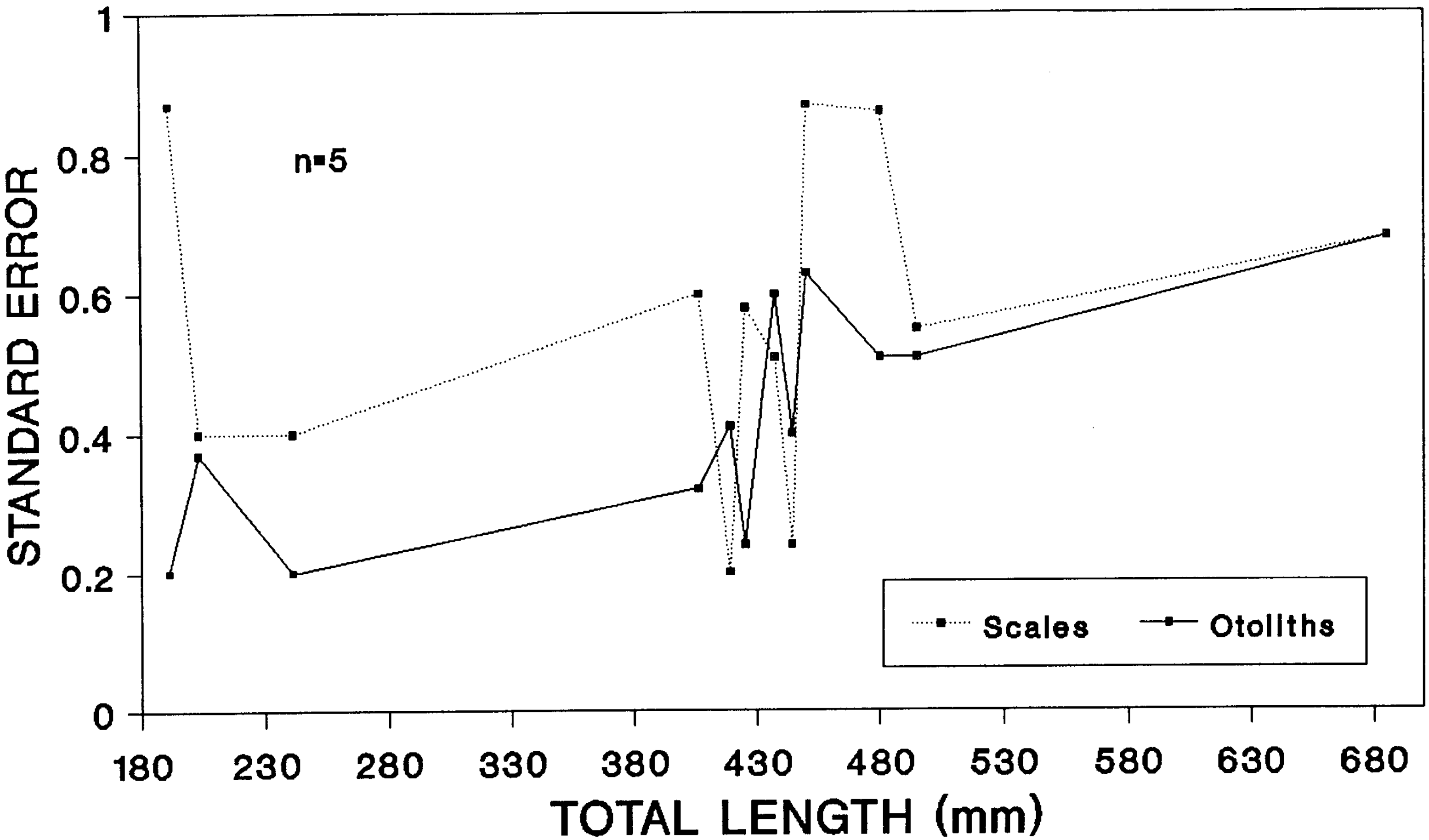


Figure 2. Relation of length and standard error of ages estimated for 12 bull trout by 5 biologists reading the same scales and otoliths.

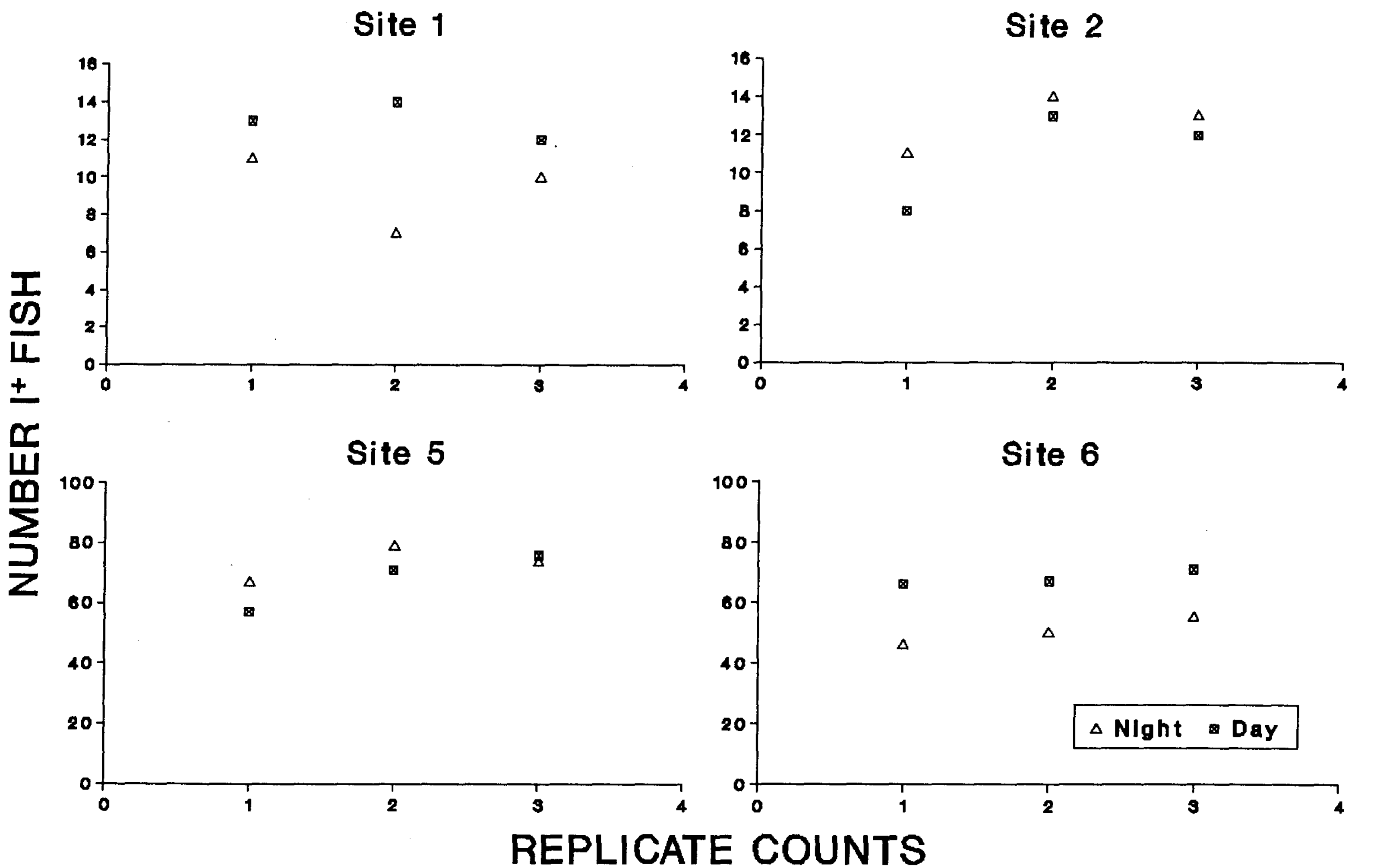


Figure 3. Numbers of age 1+ bull trout observed in four stations on Profile Creek during day and night snorkeling, August 1990.

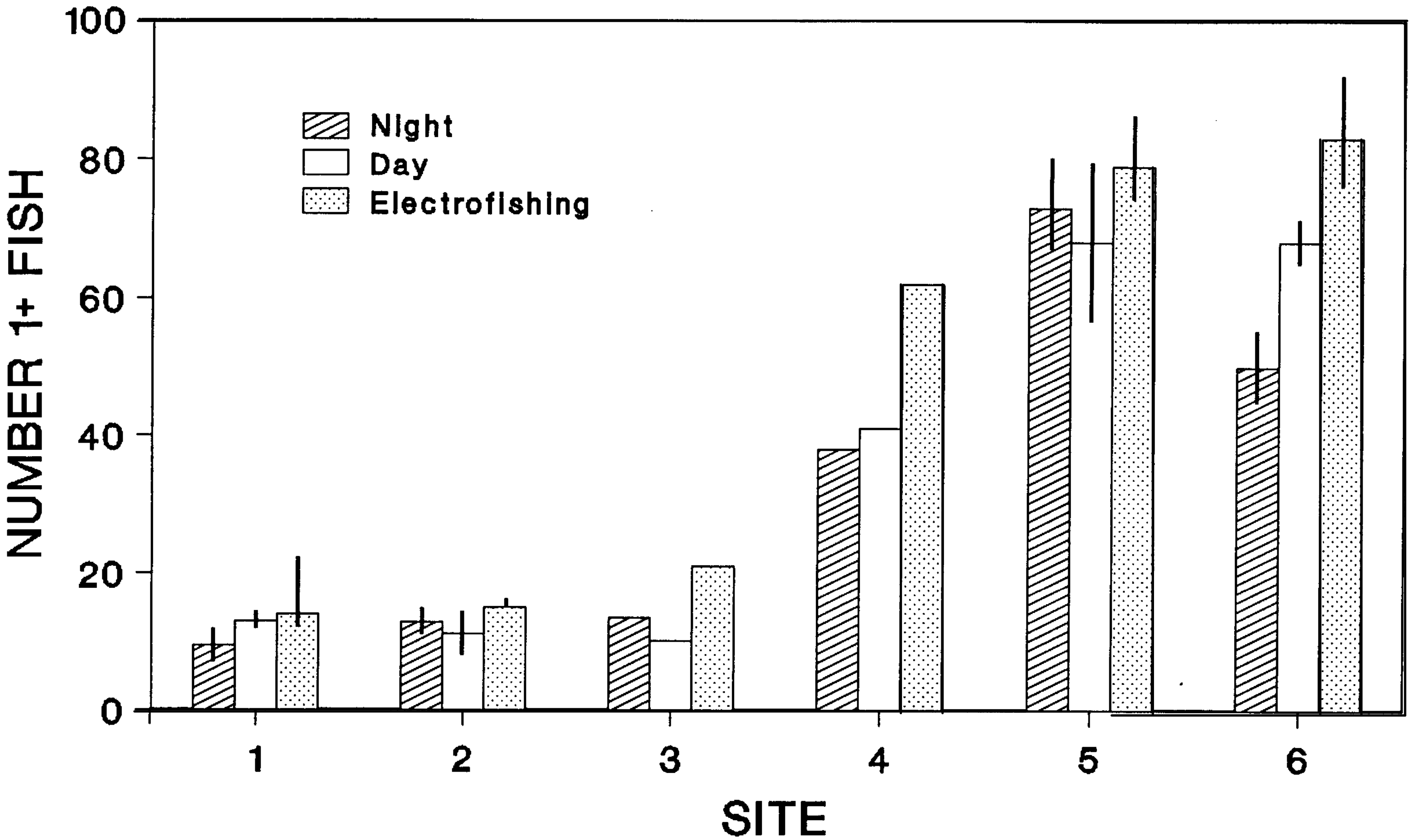


Figure 4. Numbers of age 1+ bull trout in six stations on Profile Creek estimated by day snorkeling, night snorkeling, and electrofishing, August 1990. Snorkel estimates in Stations One, Two, Five, and Six are means of three counts. Bars depict 95% confidence limits.

Table 2. Coefficients of variation for day snorkel, night snorkel, and electrofishing population estimates in four Profile Creek stations, tributary to East Fork South Fork Salmon River, August 1990.

Sampling techniques	Stations 1	2	5	6
Day snorkel	0.04	0.14	0.08	0.02
Night snorkel	0.13	0.07	0.05	0.05
Electrofishing	0.27	0.04	0.05	0.06

VTABS

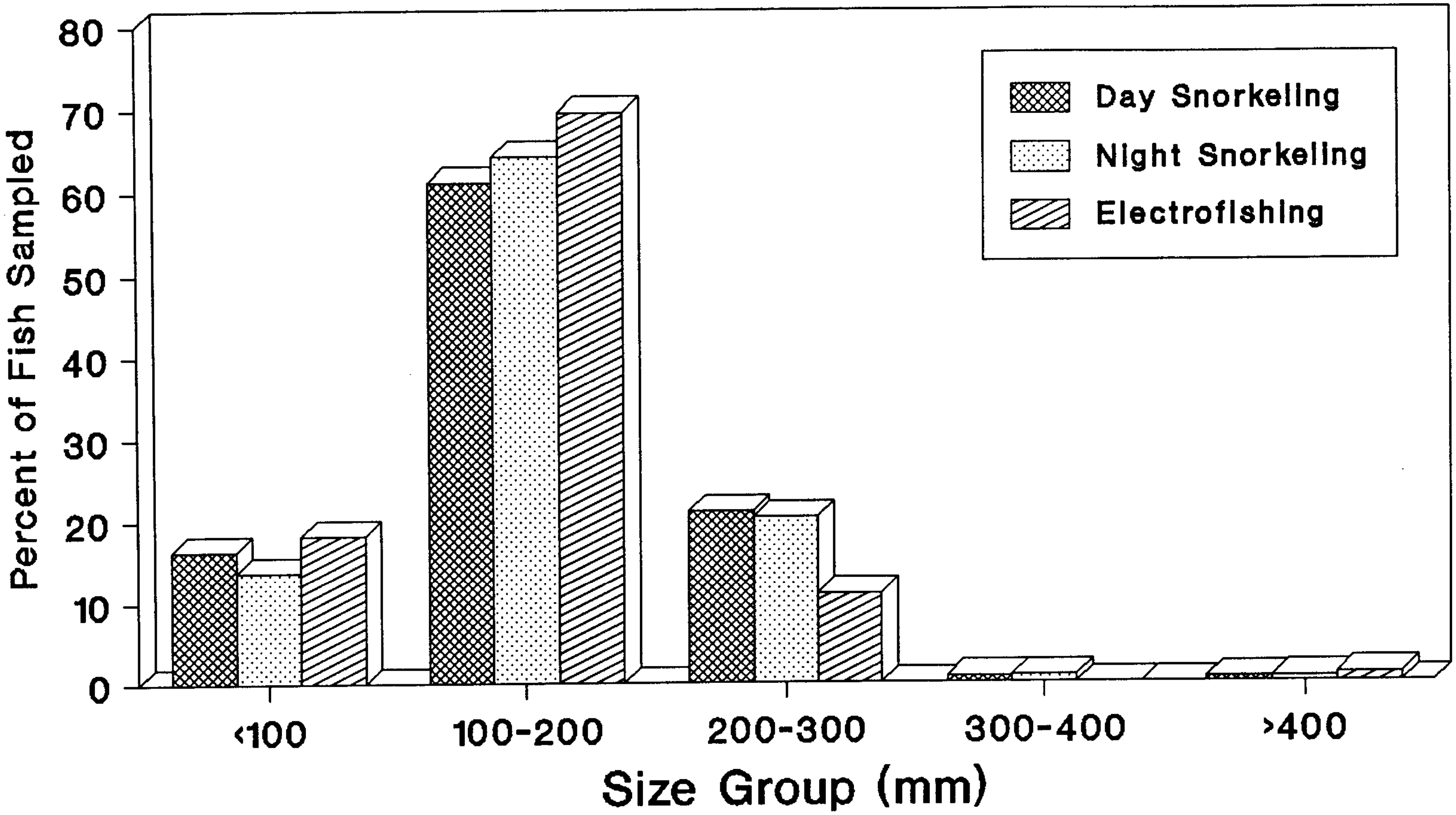


Figure 5. Length frequency of age 1+ bull trout in Profile Creek estimated by day snorkeling, night snorkeling, and electrofishing, August 1990. Data are pooled from Stations One, Two, Five, and Six.

We captured bull trout ranging from 46 mm to 630 mm in all stations during electrofishing (Appendix A). Young-of-the-year bull trout ranged in length from 46 mm to 48 mm. The length frequency suggests four age classes below 210 mm; results similar to scale analysis conducted by Thurow (1987). Thurow recommended the use of otoliths for fish over four years of age because of difficulties reading scales.

Based on a summary for the four stations where habitat was classified, bull trout densities were greatest in pools followed by runs and pocket water. Riffles were the least utilized habitats. This is the same relationship reported by Fraley et al. (1982).

We observed no major shifts in habitat use between day and night (Figure 6). Mean daytime densities were slightly higher than night estimates for all habitat types, with the exception of riffles.

DISCUSSION

Aging Comparisons

In lake trout, scales are recommended for aging only immature fish (Sharp and Bernard 1988). The authors noted consistently low scale-derived ages when compared to otoliths in larger size classes. The same authors also reported declines in precision with increasing age for both techniques. In this study, ages for fish less than 400 mm were also lower for scales than otoliths. We suspect that differences in estimated age between the two techniques will be more pronounced for larger fish.

Slow-growing long-lived fish can pose problems in accurate estimates of age (Beamish and McFarlane 1983). Scales are inappropriate for aging several species of char (Beamish 1973, Sharp and Bernard 1988). Bull trout, like other char, prefer cold water (Brown 1985; Goetz 1989). Therefore, the invalidated use of scales as aging structures for bull trout may be a problem. Aging errors can have major effects on growth and mortality estimates (Power 1978) and could ultimately result in incorrect harvest management decisions.

Conclusions from the aging work in this study are obviously limited by the number of fish available for comparison. Additional work should be conducted to assess the most reliable structure for aging bull trout. Because of concern for the species, fin ray aging should also be evaluated as a non-lethal sampling technique.

Comparisons of structures will not describe the accuracy of any structures without known age fish. Hatchery bull trout are currently being batch-marked and released into Lake Pend Orielle in northern Idaho. This represents a rare chance to actually validate age estimates for bull trout. Validation of structures should be done with these fish in the future. OTC injection should be considered if age validation work would conflict with other objectives of the marking program.

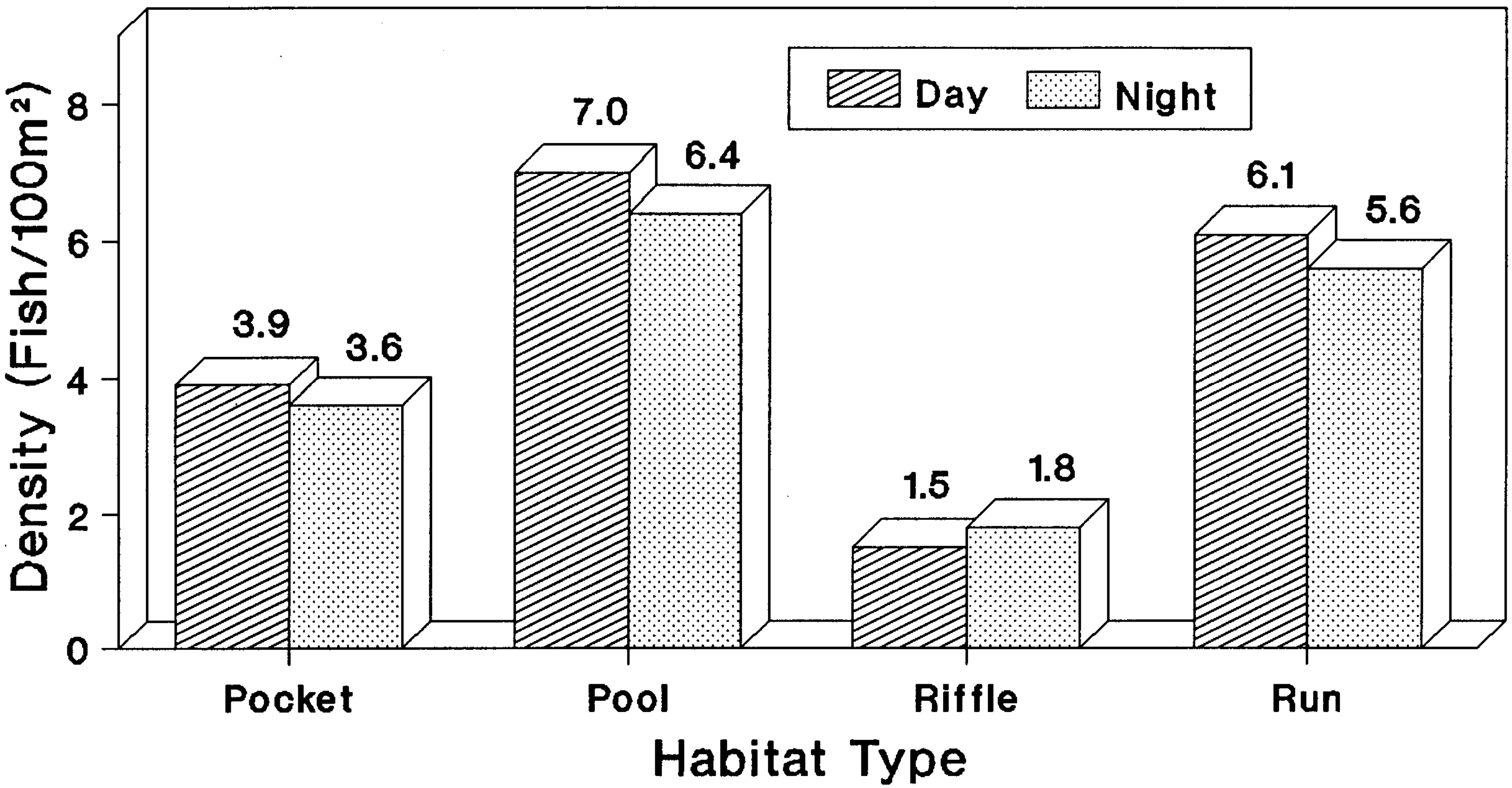


Figure 6. Comparison of age 1+ bull trout densities in four Profile Creek habitat types during day and night snorkeling, August 1990. Data are pooled from Stations One, Two, Five, and Six.

Enumeration Comparisons

We observed minimal differences between day and night snorkel counts for bull trout in five of six stations. The reason for significant decline in observed fish at night in Station Six is unknown.

Based on our efforts, night snorkeling had no advantage over day snorkeling. Our results were in direct conflict to those of Goetz (1990). Goetz reported that night snorkeling estimates on Metolious River tributaries were 2.5 times greater than day counts. Our examination of the Metolious data suggest that this figure should be used with caution. The 2.5 value was based on means from a large number of daytime counts (210 habitat units) and only 42 nighttime units and not from paired sites. Goetz did report higher upper ranges of nighttime counts for individual streams. Stenzel (1987 as cited by Goetz 1990) also observed increased densities of arctic char *Salvelinus alpinus* while night diving.

Assuming the Metolious River comparisons are valid, reasons for the discrepancy between the two studies are unclear. One potential difference between the Profile Creek and Metolious River work may be the presence of a full moon during our sampling efforts. Moonlight was bright enough that we could clearly observe bull trout in the stream without the aid of artificial light. The presence of a full moon or large amounts of artificial light reduced night counts of rainbow trout on the Henrys Fork during mid-winter (Angradi and Contour 1989).

Results of recent studies (Angradi and Contour 1989; Reihle and Griffith in review) suggest temperature can affect resident trout estimates obtained by snorkeling. At low temperatures, salmonids are often in close association with streambank cover or are in the substrate, making observation by snorkeling difficult. Temperature has also been shown to have an effect on underwater counts of juvenile chinook and steelhead (Hillman et al., in press, North American Journal of Fisheries Management). On Profile Creek, diurnal temperatures fluctuated from 8.0 to 13°C. These temperatures are well within the range that produced behavioral changes and resultant density declines in the other studies. Shepard et al. (1982) reported substrate hiding behavior of bull trout at temperatures of 8°C.

We observed no consistent effects of temperature on densities in our stations during the August sampling (Figure 7).

Temperature may play a role in bull trout use of the water column. On October 25, we re-snorkeled Stations Three and Five at water temperatures of 2°C. We observed no fish in the water column, but located bull trout under rubble in deep pools. Because of their preference for cold water, the threshold temperature eliciting behavioral responses may be lower for bull trout than for other species.

Other factors, such as habitat complexity, may also explain the differences between the Metolious and Profile studies. Instream woody debris is abundant

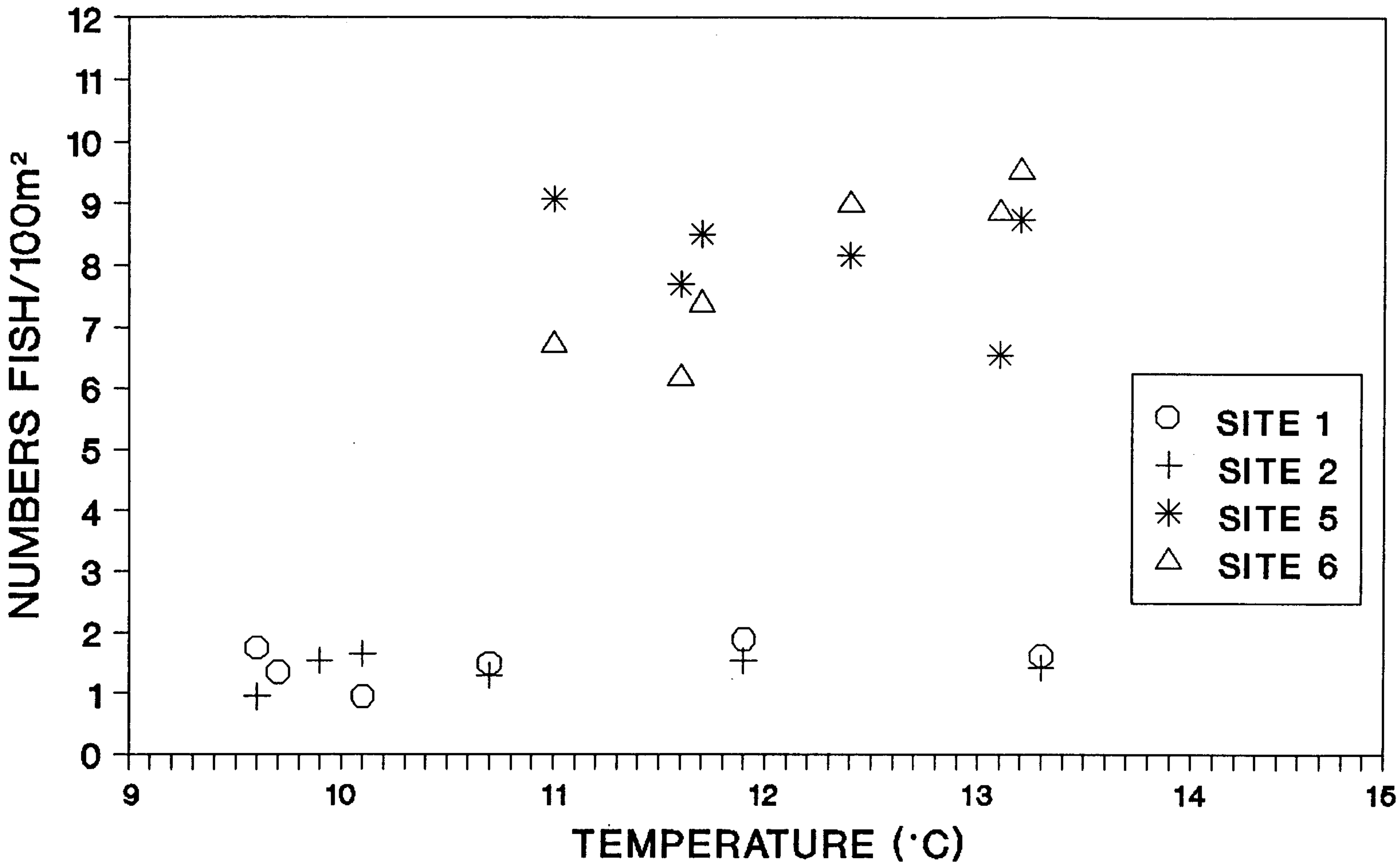


Figure 7. Relation of temperature and age 1+ on bull trout numbers observed while snorkeling Profile Creek stations, August 1990.

within the Metolious River sample sites (D. Ratliff, Portland General Electric Company, personal communication) but sparse on Profile Creek. Daytime counts on the Metolious River may be less effective if bull trout are selecting for this type of cover during the day. Additional sampling should be conducted over a range of habitats to further define the day vs night snorkeling relationship. Given the major logistic limitations of night snorkeling, differences between the two techniques would have to be similar to that of Goetz (1990) to justify a change from our current daytime methods.

One limitation of our electrofishing and snorkeling comparisons was that block nets had to be removed and reinstalled in four of six stations. We assumed no significant movement occurred during the week the net was out. We have no data on fish movements in Profile Creek that may have affected our results.

We found a small but significant difference between electrofishing density estimates and snorkel estimates (day and night). The observed difference was not large enough to be important from a management perspective. However, Shepard et al. (1982) reported nearly three times greater estimates of bull trout with electrofishing techniques. Goetz (1990) reported that day snorkeling underestimated numbers of age 1+ bull trout by more than 50% when compared to electrofishing. The association of bull trout with substrate materials (Pratt 1984; Goetz 1990) presumably accounts for these results. Goetz (1990) also reported nearly 40% higher night snorkeling counts than estimates derived from electrofishing.

Habitat type may play a role in comparability of the two techniques (Shepard et al. 1982). Bull trout snorkel counts and electrofishing estimates were similar for riffles and pocket water but varied widely for pools and runs. Conductivity also appears to be a major factor determining the comparability of electrofishing estimates to snorkel counts for other species. At low conductivities (40 µmhos), electrofishing appeared to be negatively biased (Petrosky and Hulobetz 1986). On higher conductivity waters (280 µmhos), snorkeling tended to underestimate numbers of fish. Conductivities on Profile Creek during our work were in the mid-range of these values at 102 µmhos. At these conductivities, the techniques should be comparable. Additional work should be done to quantify this relationship for bull trout waters on both ends of the conductance spectrum.

The three techniques yielded similar estimates of size structure for all stations combined, but differences for individual stations were much greater. Reasons for the differences within sites are difficult to address. In some cases, certain fish may not be "vulnerable" to either type of sampling gear, depending on habitat type, fish size, etc. Discrepancies may also be due to improper size classification while snorkeling. The latter case appeared to occur in Station Two where fish size was obviously overestimated by the diver. This station was snorkeled before the diver had measured fish during electrofishing. Snorkelers attempting to enumerate fish within various length classes should have some previous knowledge concerning sizes of fish residing in the stream. This practice has been suggested by others (Griffith 1981) but is often not adopted.

CONCLUSIONS

Our work shows that scale-derived estimates of age for bull trout can be negatively biased when compared to otoliths. Similar results have been reported for other species of char. Until aging methods are validated, managers should use existing bull trout age estimates with caution, especially when developing regulation alternatives. If scale ages are used in regulation selection, managers should consider that growth has been overestimated.

Our results showed no differences between day and night snorkeling counts for bull trout. The only other study addressing this topic suggests that daytime snorkeling will seriously underestimate densities. Until we understand the factors influencing the accuracy of estimates, managers should be cautious. Bull trout inventories should subsample a small number of stations at night to determine whether a serious bias exists in daytime estimates.

Study results also confirmed past findings that day snorkeling underestimates bull trout numbers when compared to electrofishing. Although our differences were small, past studies suggest this difference can approach 300%. If an absolute estimate of bull trout density is considered critical, electrofishing should be conducted whenever feasible. If snorkeling is the only available option, biologists should again acknowledge the likely possibility of sampling bias.

RECOMMENDATIONS

1. Conduct an age validation study on Lake Pend Orielle using Sandpoint Hatchery bull trout.

2. Consider existing growth estimates for bull trout as optimistic when developing regulation alternatives until scales have been validated as reliable aging structures.

3. Conduct additional comparisons of day vs night snorkeling in waters with a range of habitat variables and during at least one different period of the lunar cycle.

4. Snorkeling inventories for bull trout should confirm their results by electrofishing a subsample of stations whenever possible.

5. When snorkel techniques are used, replicate counts should be conducted in a small sub-sample of sample sites to provide some estimate of counting error.

ACKNOWLEDGEMENTS

We would like to thank Pat Saffel, Suzi Adams, Andrew Whipple, and Reg Reisenbichler for assistance with snorkel data collection. Tom McArthur and Jack Van Deventer provided statistical suggestions. Jon Dudley assisted with data analysis. Melo Maiolie, Vern Ellis, Greg Mauser, and Jeff Day collected otoliths for the aging work.

LITERATURE CITED

Alvord, W. 1954. Validity of age determination from scales of brown trout, rainbow trout, and brook trout. Transactions of the American Fisheries Society. 83:91-103.

Angradi, T. and C. Contour. 1989. Henrys Fork fisheries investigations. Idaho Department of Fish and Game, Job Completion Report, Project F-71-R-12, Boise.

Barber, W.E. and G.A. McFarlane. 1987. Evaluation of three techniques to age Arctic char from Alaskan and Canadian waters. Transactions of the American Fisheries Society. 116:874-881.

Beamish, R.J. 1973. Determination of age and growth of populations of the white sucker Catostomus commersoni exhibiting a wide range in size at maturity. Journal of the Fisheries Research Board of Canada. 30:607-616.

Beamish, R.J. and G.A. McFarlane. 1983. The forgotten requirement of age validation in fisheries biology. Transactions of the American Fisheries Society. 112:735-743.

Bisson, P.A., J.L. Nielsen, R.A. Palmason, and E. Grove. 1982. A system of naming habitat types in small streams, with examples of habitat utilization by salmonids during low stream flow. Pages 62-73 in N.B. Armatrout, editor. Acquisition and Utilization of Aquatic Habitat Inventory Information. American Fisheries Society, Western Division, Bethesda, Maryland.

Brown, P. 1985. Dolly Varden culture in British Columbia. Pages 62-67 in Proceedings of the Flathead River Basin Bull Trout Biology and Population Dynamics Modeling Information Exchange, Whale Creek Community Centre, Montana.

Corsi, C. and S. Elle. 1989. Regional fisheries management investigations: Region 6 (Idaho Falls) rivers and streams investigations -- Big Lost and Little Lost Rivers, and Birch and Medicine Lodge Creeks survey. Idaho Department of Fish and Game, Job Performance Report, Project F-71-R-12, Boise.

Fraley, J., D. Read, and P. Graham. 1981. Flathead River fisheries study. Montana Department of Fish, Wildlife and Parks, Kalispell.

Goetz, F. 1989. Biology of the bull trout Salvelinus confluentes a literature review. USDA, Forest Service, Willamette National Forest, Eugene, Oregon.

Goetz, F. 1991. Bull trout life history and habitat study. USDA, Forest Service, Deschutes National Forest, Final Report, Contract 43-04GG-9-1371, Oregon.

Griffith, J.S. 1981. Estimation of the age-frequency distribution of stream dwelling trout by underwater observation. Progressive Fish-Culturist. 43(1):51-53.

Hankin, D.G. and G.H. Reeves. 1988. Estimating total fish abundance and total habitat area in small streams based on visual estimation methods. Canadian Journal of Fisheries and Aquatic Sciences. 45:834-844.

Hillman, T.W., J.W. Mullan, and J.S. Griffith. In press. Accuracy of underwater counts of juvenile chinook and coho salmon and steelhead. North American Journal of Fisheries Management.

Irving, D.B. 1986. Lake and reservoir investigations: Pend Oreille trout and char life history study. Idaho Department of Fish and Game, Job Performance Report, Boise.

Johnson, L. 1976. Ecology of Arctic populations of lake trout Salvelinus namaycush, lake whitefish Coregonus clupeaformis, Arctic char S. alpinus, and associated species in unexploited lakes of the Canadian Northwest Territories. Journal of the Fisheries Research Board of Canada. 33:2459-2488.

Mallet, J. 1964. Biological and economic survey of fisheries resources in Lake Pend Oreille. Pages 19-42 in The Lake Pend Oreille Creel Census and Life History Studies. Idaho Department of Fish and Game, Boise.

Petrosky, C.E. and T.B. Holubetz. 1987. Evaluation and monitoring of Idaho habitat enhancement and anadromous fish natural production. USDE, Bonneville Power Administration, Division of Fish and Wildlife, Annual Report 1986, Contract No. DE-A179-84BP13381, Portland, Oregon.

Power, G. 1978. Fish population structure in Arctic lakes. Journal of the Fisheries Research Board of Canada. 35:53-59.

Pratt, K.L. 1984. Habitat use and species interactions of juvenile cutthroat Salmo clarki lewisi and bull trout Salvelinus confluentes in the Upper Flathead River basin. Master's thesis. University of Idaho, Moscow.

Pratt, K.L. 1985. Lake and reservoir investigations: Pend Oreille trout and char life history study. Idaho Department of Fish and Game, Job Performance Report, Boise.

Seber, G.A.F. and E.D. Le Cren. 1967. Estimating population parameters from catches large relative to the population. Journal of Animal Ecology. 36:631-643.

Sharp, D. and D.R. Bernard. 1988. Precision of estimated ages of lake trout from five calcified structures. North American Journal of Fisheries Management. 8:367-372.

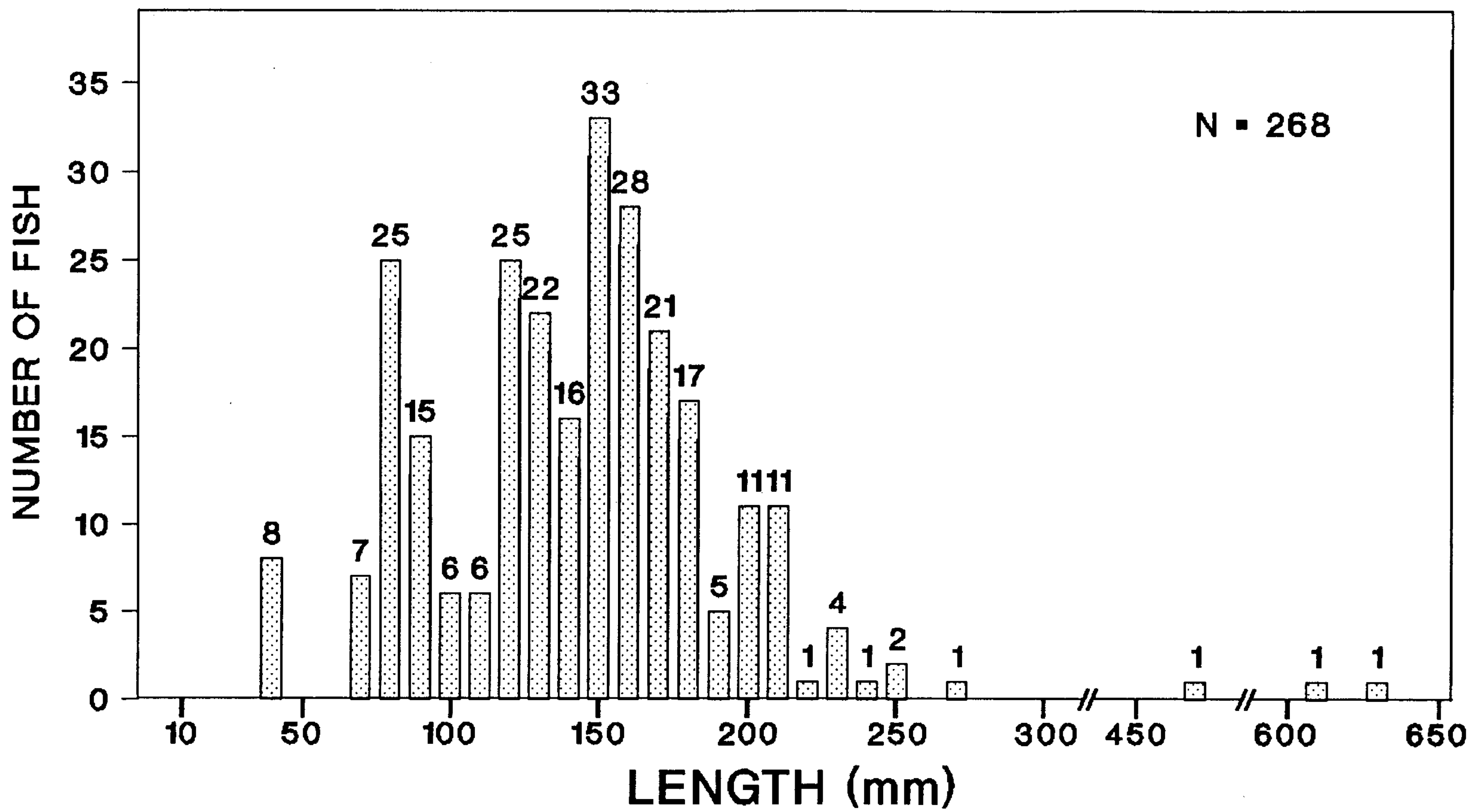
Shepard, B.B., J.J. Fraley, T.M. Weaver, and P. Graham. 1982. Flathead River fisheries study. Montana Department Fish, Wildlife and Parks, Kalispell.

Stenzel, A. 1987. Ecological aspects of juvenile Arctic char Salvelinus alpinus in the Koroc River, Ungava Bay, Quebec. Master's thesis. University of Waterloo, Waterloo, Ontario.

Thurow, R. 1987. Evaluation of the South Fork Salmon River steelhead trout restoration program. Idaho Department of Fish and Game, Completion Report, Contract No. 14-16-0001-86505, Boise.

Van Deventer, J.S. and W.S. Platts. 1989. Microcomputer software system for generating population statistics from electrofishing data-User's guide for MicroFish 3.0. USDA, Forest Service, Intermountain Research Station, General Technical Report INT-254, Ogden, Utah.

APPENDICES



Appendix A. Length frequency of all bull trout collected by electrofishing in six Profile Creek stations, August 1990.

JOB PERFORMANCE REPORT

State of: Idaho

Name: River and Stream Investigations

Project No: F-73-R-13

Subproject No.: II

Title: Hagerman Bait-Hooking Study

Study No.: IV

Job No.: 3

Period covered: March 1, 1990 to March 31, 1991

ABSTRACT

A study was conducted at the Hagerman State Fish Hatchery to evaluate a method of minimizing bait-hooking mortality. Mortality after two months ranged from 74% to 77% for deep-hooked fish with hooks removed. Cutting the line on deep-hooked fish resulted in one-third less mortality that ranged from 47% to 49% in the two trials. Seventy-four percent of the cut-line survivors shed the hook during the study. In both trials, there was a trend for higher condition in light-hooked and control groups, but the differences were small. Results of ANOVA indicated no significant differences in treatment condition factors ($p=0.05$) for either of the two trials. Available data indicate that cutting the line on deep-hooked fish can substantially reduce bait-hooking mortality. The average reduction in mortality for salmonids observed in other studies was 53% for deep-hooked fish. Reductions in hooking mortality could make this gear more acceptable for regulations requiring release of some fish.

Author:

Dan Schill
Senior Fishery Research Biologist

90REPRT

INTRODUCTION

Since the efforts of Westerman (1932), over 50 studies have been conducted to assess mortality associated with the act of catching and releasing sport fish. Bait-hooking losses are generally considered to be 25% to 30% for salmonids (Wydoski 1976; Monguillo 1984).

Relatively few investigators have examined ways to minimize bait-hooking mortality. Two studies have reported reductions in mortality with increased hook size (Shetter and Allison 1955; Hulbert and Engstrom-Heg 1980). In the latter study, authors also reported an inverse relationship between hook size and catchability of test fish.

Several authors have investigated the merits of cutting the leader on deeply-hooked fish allowing the hook to remain. Mason and Hunt (1967) first evaluated this approach with hatchery rainbow trout (TL=145 mm) that had swallowed a baited hook. Four months after release, mortality for fish with hooks removed in the traditional manner was 95%. Mortality for those fish in which the line had been cut allowing the hook to remain was 34%.

Two subsequent studies followed the same general approach (Warner 1979; Hulbert and Engstrom-Heg 1980). Results from both suggest substantial improvements in survival can be derived by cutting the leader. More recent work (Burdick and Wydoski 1987; Weidlein 1987) has been done with largemouth bass Micropterus salmoides and bluegill Lepomis machrocheilus. Results show even greater benefits for these species.

Despite consistent evidence of benefits from cutting the line, many fishery managers appear uninformed or skeptical about the technique. Skeptism may be warranted because of limitations in past study designs. For example, in the two most detailed cut-the-line studies (Mason and Hunt 1967; Hulbert and Engstrom-Heg 1980), test fish were anesthetized prior to hooks being removed. This is a major departure from handling techniques in a typical fishery. Others have reported short holding periods for test fish (Burdick and Wydoski 1987; Warner 1979) and may not have documented full mortality.

We undertook a cut-the-line study that better simulated typical release procedures by including the angling public. We anticipated that public involvement would make any study results more credible and aid in future angler education efforts.

OBJECTIVES

1. To compare mortality rates and condition factors for deeply-hooked rainbow trout released with conventional and cut-the-line techniques.

2. To compare mortality of light- and deep-hooked fish.

3. Assess the effects of hook location on survival for cut-line fish.

90REPRT

STUDY SITE

The study was conducted at the Hagerman State Fish Hatchery in southcentral Idaho from June 22 to August 23, 1990. The water source in the hatchery was from nearby Riley Creek, a small spring-fed stream. Temperatures during angling portion of the study ranged from 15°C to 19°C, making it one of the warmest water hooking studies conducted with salmonids. Dimensions of all raceways used were 35 m long, 4.5 m wide, and 0.75 m deep.

METHODS

The design was similar to that reported by Mason and Hunt (1967). We conducted separate trials using two groups of fish. The groups were standard production fish and a second group graded for slightly larger size and body condition. Both groups (3,000 production fish - Mean TL=228 mm, SD=18.9, and 3,500 graded fish-Mean TL=245 mm, SD=18.2) were removed from a single nearby raceway and placed in adjoining raceways one week prior to fishing. Lengths were significantly different between these two test groups (t-test, $p < .001$).

Handling

On June 22, 1990, project personnel began by fishing on the production group (hereafter designated "biologist" trial). The "angler" trial was begun the following day using the graded group of fish. Volunteers for the angler trial were a cross section of anglers 6 to 55 years in age. All fishing was done with a size 8 hook baited and a worm. We used commercially available worm threaders to increase the incidence of deep-hooking. Fish were permitted to "take" the bait and swim around for some time prior to setting the hook.

Playing time was left to the discretion of the individual fisherman. Anglers hoisted the fish over the lip of the raceway and into a metal tub full of water where the fish was examined by a biologist. Those fish hooked in the gills, esophagus, or stomach were designated as deep-hooked. The remainder were classified as light-hooked.

Fish were fin-clipped depending on the location of the hook (treatment) and trial group. Common treatment groups in both trials received the same clip. Fish in the biologist trial also received a caudal fin punch. The treatments, sample size, and associated fin clips are presented in Table 1.

Upon completion of the marking process, anglers were instructed to release the fish back into the metal tub. Half of the deep-hooked fish had the hook removed, while the other half were released by cutting the leader at the tip of the fishes snout. Each angler alternated between removing the hook and cutting the leader. We provided each angler with forceps, pliers, or hook disgorgers to use as they desired. Hooks were removed from all light-hooked fish. Released

Table 1. Summary of treatments, sample size, and fin clips used in the Hagerman bait-hooking study, June 22 to August 23, 1990.

	Biologist Trial			Angler Trial			
	Light-hooked	Deep cut-line	Deep removed	Light-hooked	Deep cut-line	Deep removed	Control
Sample size	75	80	55	152	156	107	150
Fin clip	adipose-C[a]	left pelvic-C	right pelvic-C	Adipose	left pelvic	right pelvic	opercle punch

[a]C denotes caudal fin punch.

VTABS

fish were immediately transferred to a five gallon bucket for transport to a single holding raceway. Transport time to the raceway ranged from 10 to 30 seconds.

Data Collection and Analysis

Mortality

Mortality by treatment was recorded daily for two months. We used a Chi-square analysis to test the null hypothesis that mortality was independent of treatment in both trials. Yates correction for continuity was used when appropriate (Zar 1974). For those analyses producing significant differences among all treatments, we subdivided the Chi-square analyses to further examine mortality rates (Zar 1974). We used a Chi-square analysis for heterogeneity to determine if the results from the angler- and biologist caught test groups could be pooled (Zar 1974).

Condition Factors

All study survivors were weighed and measured to the nearest gram and mm. Condition was calculated using the formula $K = W/L^3 \times 10$ (Lagler 1956). We compared mean condition for study survivors from the various treatment groups using one-way ANOVA. We assumed that fish from the individual treatments had the same initial condition factors.

Autopsies

We conducted autopsies on a subsample of cut-line mortalities. We also autopsied all cut-line survivors. For those cut-line survivors with **a** hook still present, hook location and any observable damage was noted.

We summarized hook locations for cut-line mortalities and survivors. Fish hooked in the liver, pericardial sac/heart, or gills were categorized as organ-hooked. Those in the esophagus, stomach, or intestine were grouped separately. We tested for association of hook location with survival using Chi-square analysis.

We found few hooks in. initial autopsies of cut-line fish. To facilitate the work, we used a coded wire tag detector to detect the presence or absence of hooks. We conducted autopsies on 30 fish after interrogating them with the detector. Hook presence or absence was correctly predicted in all cases.

RESULTS

Mortality Rates

There were major differences in mortality rates among treatments in both the angler and biologist trials (Figure 1). Mortality after two months ranged from 0.74 to 0.77 for deep-hooked fish with hooks removed. Cutting the line on deep-hooked fish resulted in approximately one-third less mortality. The observed mortality in the two trials was 0.47 and 0.49. Mortality rates for all treatments in the biologist trials were greater than corresponding treatments in the angler test group.

Chi-square analysis indicated significant differences in mortality rates for both trials. Significant differences were found among all treatments within trials (Appendix A).

The hooking mortality was derived from the original number of fish in each treatment and numbers of marked fish found dead by Hagerman Hatchery personnel. At the end of the study, 25 fish, or 3%, of the original number were unaccounted for. Losses must have occurred through predation, scavenging, or emigration from the raceway.

We made the assumption that all missing fish from each marked group had died from hooking wounds and recalculated Chi-square statistics. This alternative analysis resulted in the same conclusions. There were significant differences in mortality between all treatments. Because of these results and the small number of fish involved, we have assumed the original proportions are accurate observations of the hooking mortality in the study.

Differences in mortality between the two trials were minimal except for two light-hooked test groups. Mortality in light-hooked fish ranged from 0.02 to 0.13. Despite these differences, the study results can be pooled based on the heterogeneity Chi-square analysis (= 1.39, df=2). Pooled estimates for the entire study were 0.75 for deep-removed, 0.48 for cut-line, and 0.06 for light-hooked fish.

Pattern of Mortality

The majority of deaths in the deep-hooked groups were within 24 hours. In the angler trial, 54% and 83% of all cut-line and hook-removed mortalities, respectively, occurred within the first 10 hours of the study. Ninety-two percent of all deep-hook-removed deaths occurred during the first week of the study. Cut-line mortality was slightly delayed, with 83% of all mortality occurring during the initial week (Figure 2).

In the biologist trial, the pattern of mortality was similar for deep-hooked fish. There was a delayed response for light-hooked fish in the biologist group, but the sample size was small (Figure 2).

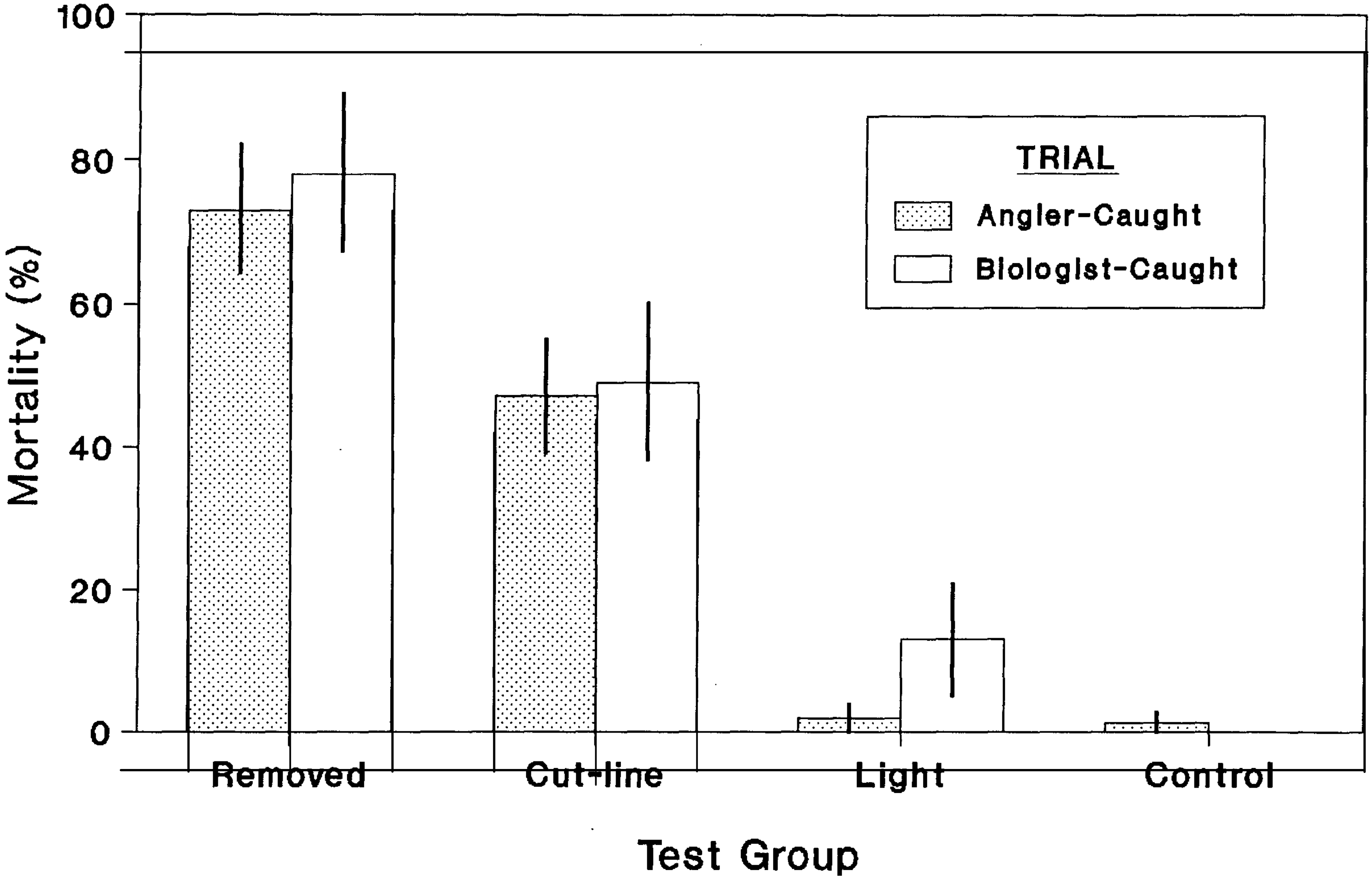


Figure 1. Mortality of test and control groups of hatchery rainbow trout observed in two trials during the Hagerman bait-hooking study from June 22 to August 23, 1990. Cut-line and hook-removed groups were deeply hooked. Bars denote 95% confidence limits.

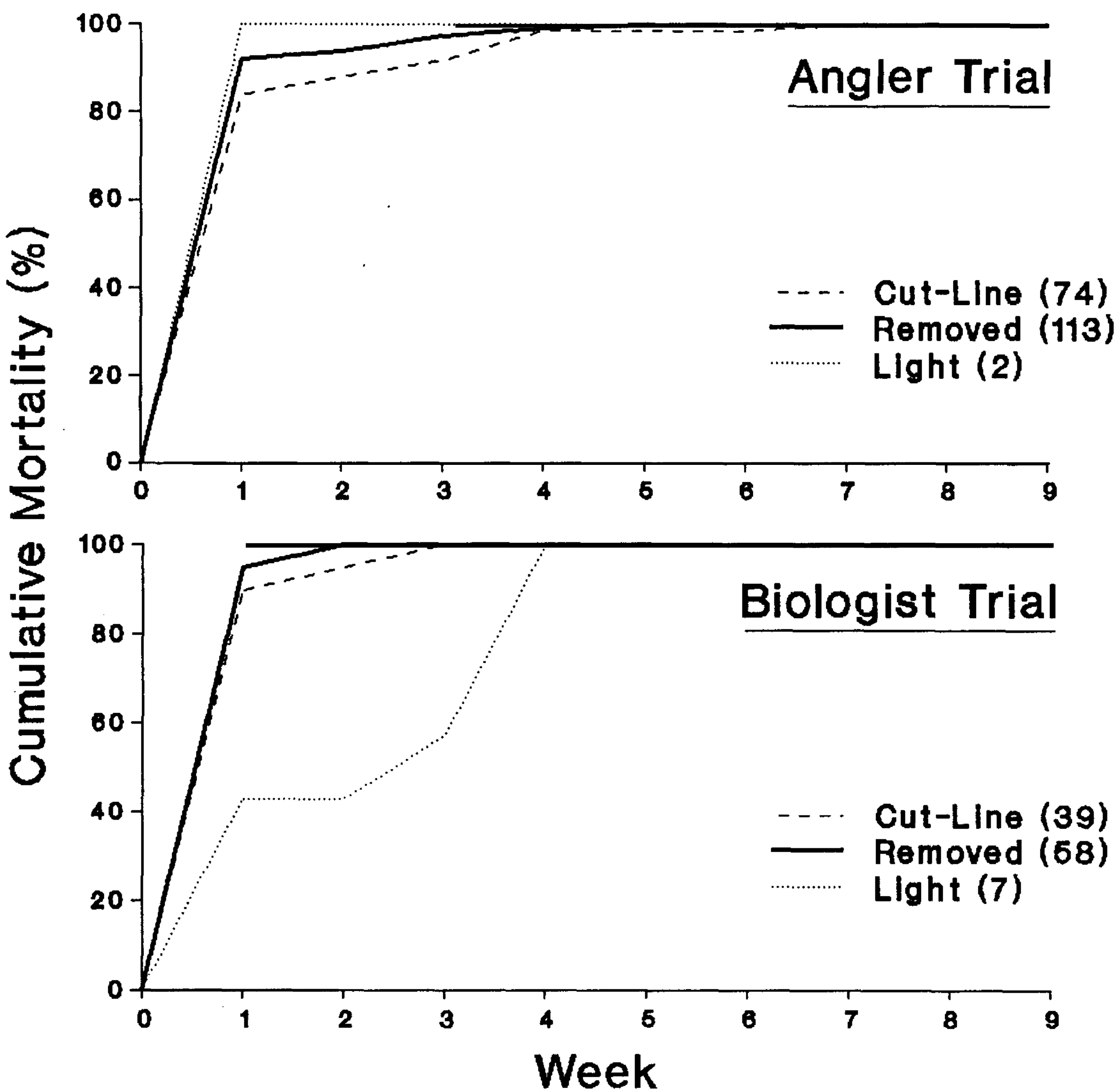


Figure 2. Cumulative mortality (percent of all fish dying) of hatchery rainbow trout observed in two trials during the Hagerman bait-hooking study from June 22 to August 23, 1990. Cut-line and hook-removed groups were deeply hooked. Sample size in parentheses.

Condition

A total of 458 survivors were used in the condition comparisons. Mean condition ranged from a low of 1.24 in cut-line fish from the biologist trial to 1.36 in light-hooked fish from the angler trial. Condition factors were consistently lower in the biologist test group (Figure 3), probably as a result of the grading process.

For both trials, there was a trend for higher condition in light-hooked and control groups, but the overall differences were insignificant. Condition factors of cut-line fish met or exceeded that of deep-hook removed fish in both trials. Results of ANOVA indicate no significant differences in condition among treatments ($p=0.05$) for either the angler ($F=1.366$, $df=3$) or biologist trials ($F=2.921$, $df=2$).

Autopsies

Of 17 hook-removed fish surviving two months, we could find no evidence of hook damage. A total of 53 cut-line fish were autopsied, 29 of which had no hook present and showed no visible signs of injury. The remaining fish (24) had hooks present in a variety of anatomical sites. Most of these hooks were found in the esophagus and anterior half of the stomach wall. Only one hook had passed through the stomach to the ascending intestine (Appendix B). Four fish had hooks penetrating both the ventral stomach wall and the anterior portion of the liver.

Use of the coded wire tag detector enabled us to autopsy only fish with hooks in them. We found that 74% of the cut-line survivors had managed to shed the hook during the 2-month study.

Examination of limited numbers of cut-line mortalities produced different results. All but one fish (99.6%) retained the hook. The liver was the most common hook location for mortalities, followed by gills and the pericardial sac/heart area (Appendix B). Eighty-seven percent of the cut-line mortalities were organ-hooked. Chi-square analysis indicates that survival was dependent on hook location ($p < 0.001$).

DISCUSSION

Most hooking mortality occurs during the first few days (Wydoski 1977), but the cut-line group in our study obviously warranted a holding period longer than one week. We observed no mortality of cut-line fish during the last month of the study. Although four surviving fish had hooks imbedded on the edge of the liver, overall appearance of these fish was good. We assumed our 2-month study accounted for all mortality that was going to occur in the test groups.

Cutting the line on deep-hooked fish can have a major effect on bait-hooking mortality. We observed a reduction in deep-hooking mortality by 36% when

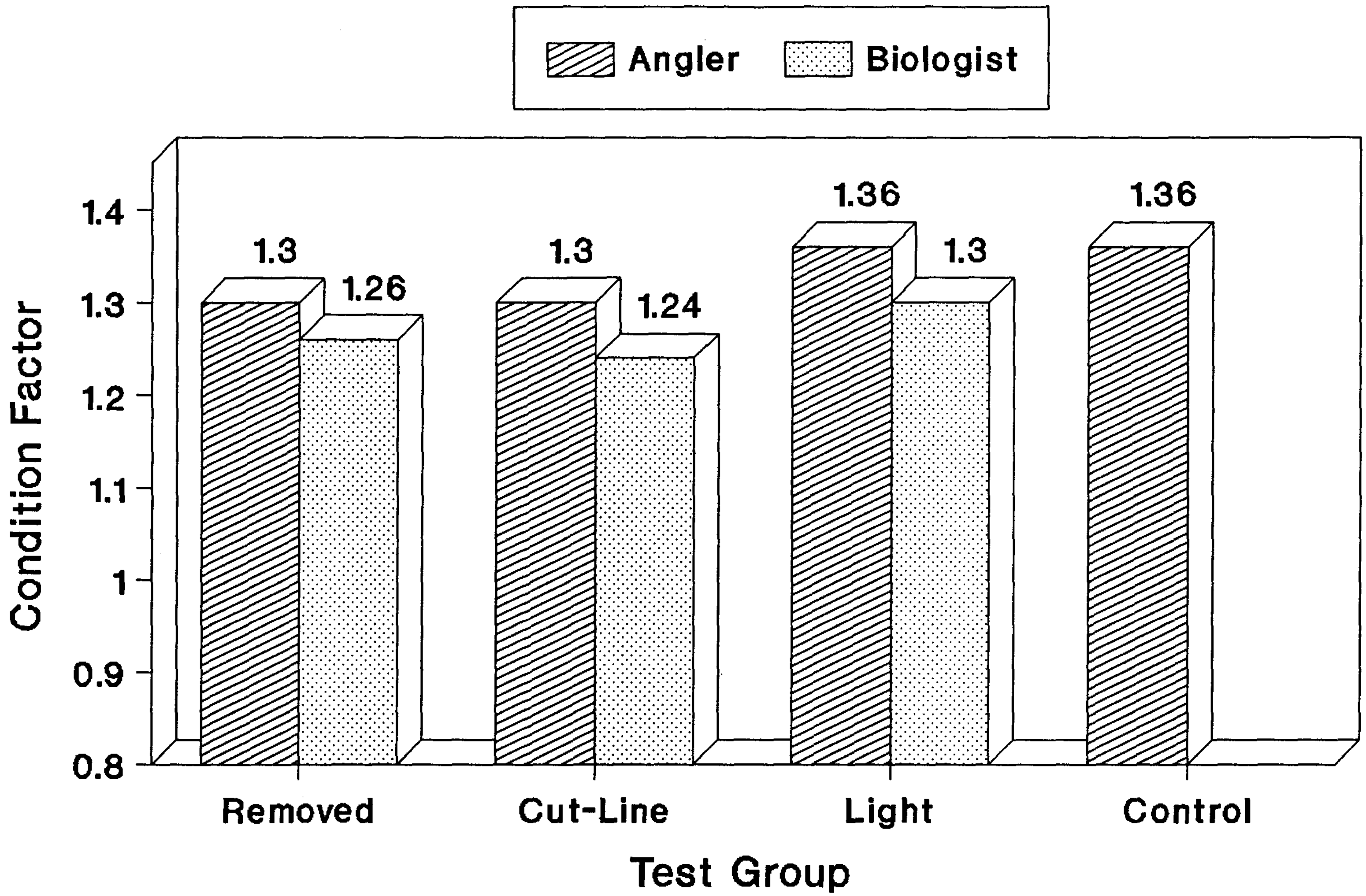


Figure 3. Condition of surviving hatchery rainbow trout at the termination of two trials during the Hagerman bait-hooking study from June 22 to August 23, 1990. Cut-line and hook-removed groups were deeply hooked.

compared to hook removal. These results are similar to the 38% reduction reported by Warner (1979) for 315 mm to 318 mm Atlantic salmon *Salmo salar.* Both estimates are well below the 61% to 66% estimate of Mason and Hunt (1967) for rainbow trout. Hulbert and Engstrom (1980) reported a mortality reduction of 73% for brown trout hooked in similar locations.

Taken collectively, the above studies suggest that mortality of deep-hooked salmonids can be reduced by approximately one- to two-thirds if anglers cut the line. The average reduction in mortality observed in the above studies is 53%. Applicability of these studies to wild populations, however, is unknown. Mongillo (1984) suggested that wild fish may suffer two to three times greater hooking mortality than hatchery fish, but direct comparisons are unavailable. Work has been done on wild centrarchids, however, and results suggest benefits of that magnitude. Weidlein (1987) reported a mortality reduction of 88% by cutting the line for largemouth bass *Micropterus salmoides* held 20 days. Deep-hooked bluegill mortality was reduced from 18% to 0% by cutting the line (Burdick and Wydoski 1987). However, holding periods in this study were limited to three days.

Our study results should not be used as an estimate of overall bait-hooking mortality. We deliberately attempted to maximize the frequency of deep hooking in this effort. Also, the study was done in a hatchery with unknown effects on the incidence of deep hooking. Hatchery studies examining hooking mortality may be biased because participants can see fish "taking" the bait (Warner 1976) and thus influence the incidence of deep hooking. Lightly-hooked fish caught with bait suffer minimal mortality, as do fly- or lure-caught fish (Hulbert and Engstrom-Heg 1980). Thus, reductions in bait-hooking losses by cutting the line would be dependent on overall deep-hooking mortality rates.

Several studies outside the hatchery raceway have shown that bait-hooked fish are often lightly-hooked (Hunsaker et al. 1970; Stringer 1967; Hulbert and Engstrom-Heg 1980; Warner and Johnson 1978). The incidence of deep hooking in these studies with four different salmonid species ranged from 30% to 55% with a weighted average of 35%. A weighted mean estimate of bait-hooking mortality from the same studies averaged 30% (n=863).

Hulbert and Engstrom-Heg (1980) suggested overall hooking mortality in their pond situation could have been reduced from 22% to only 7% if the leaders had been clipped on all deep-hooked fish.

Major declines in body condition did not result from leaving a hook intact in the digestive tract of rainbow hatchery trout. Mason and Hunt (1967) also found similar condition factors when comparing cut-line fish to other treatments. All work on this topic has been done with hatchery fish in raceways. Whether these results apply to wild fish in natural situations is unknown.

The condition results are not surprising when considering that 74% of the test fish shed the hook prior to the conclusion of the study. Mason and Hunt (1967) also reported a high incidence of hook shedding in two months (58%). The exact mechanism is unknown, but seems best explained by direct passage through the gills or the mouth. Autopsy results provided no evidence that hooks travel out the anal vent. A single hook was located in the anterior end of the ascending intestine. As in Hulbert and Engstrom-Heg (1980), we did observe oxidation, but all hooks remained in a single piece during the study period based on autopsy results. A preliminary study of hook oxidation rates in stomachs of hatchery fish (Schill, Idaho Department of Fish and Game, unpublished data) suggests that standard commercial hooks will not oxidize completely during a 2-month period.

Fishery biologists may be skeptical about the utility of cutting the line. Since the early efforts of Shetter and Allison (1955), fishery biologists have been taught that bait fishing and quality trout regulations are incompatible. Agencies have gone to great lengths to educate the public along similar lines. Bait fishing should not necessarily be ruled out for special regulation waters. Studies documenting the success of special regulations permitting bait are increasing in the literature (Turner 1986; Orciari and Leonard 1990; Carline et al. 1990). Carline et al. (1990) suggested that bait restrictions can, in fact, be justified biologically in many special regulation situations. The question may be related to the goal of the management action. If the goal is to provide the maximum biological potential possible or to prevent population collapse, a bait restriction may be justifiable. If the goal is to achieve **a** target but not necessarily maximum catch rate or fish size, a bait restriction may not always be needed.

Recent population modeling for the Big Wood River indicated that the fishery could improve substantially with a slot limit that permitted the use of bait to meet management goals of catch rate and size (Thurow 1990). Thurow (1990) predicted that a bait-allowed regulation would produce more large fish, but not as many as **a** no bait one. Many anglers were unwilling to accept a bait restriction. The controversy resulted in a temporary court injunction by bait anglers blocking the bait restriction. An eventual compromise was reached and the river was subdivided into two segments, one permitting the use of bait.

Court challenges of special regulations are not new (Bain 1987). They may become common, however, as human population increases place more stress on wild trout populations via habitat loss or increasing angler numbers. The use of bait in some special regulatin waters may eliminate some of these problems in the future.

A simple analysis shows the possible benefits of special regulations with bait allowed. Given a catchable population of 10,000 fish subjected to catch-and-release angling and assuming 1) 75% of the population is caught and released each year; 2) 50% of the fish are caught with bait; and 3) bait-hooking mortality is 30% (i.e. traditional release); bait-related mortality would be 1,125 fish or 11.3% of the total population. An additional 1.9% of the population would be expected to succumb from fly- and lure-related mortality (5% rate). The combined level of hooking mortality (equivalent to 13.2% exploitation) may reduce a fishery below its ultimate potential, but would still provide benefits well above a liberal harvest situation. Whether the additional 11.3% mortality is important depends on management goals, fishery productivity, and social needs.

The above example can also demonstrate the potential benefits of the leader cutting technique. Assuming that deep-hooking accounts for essentially all bait-related deaths, reductions of 33% to 66% via cutting the line would result in a population mortality rate of 6% to 10% vs 13.2% using traditional release techniques.

Obviously all anglers will not cut their leaders. Even widespread education efforts would not reach all anglers. Others may be unwilling to adopt the practice for reasons including expense, time loss, or humane concerns. We do not know the percentage of salmonid anglers who currently cut leaders. Weidlein (1987) reported that 20% of Shasta Lake bass anglers cut the line on deep-hooked fish. Estimates of current release practices followed by education campaigns and subsequent evaluations would show benefits of angler education.

Given current perceptions on bait-hooking mortality, the leader cutting technique may prove more useful in general regulations than for special regulations on individual waters. Restrictive regulations have been adopted over large geographic areas in Idaho to reverse declines in cutthroat trout. The regulations (1 fish over 356 mm and a 2-fish slot limit) cover over 30,000 km^2; an area too large to consider a bait restriction. Educating the public about better release techniques would seem appropriate in these situations. Hunt (Wisconsin Department of Natural Resources, Waupaca, personal communication) estimated 260,000 trout could be saved each year in Wisconsin if anglers cut leaders when releasing fish.

Little effort appears to have been made to encourage anglers to cut leaders. A few states have included a short informational note in their fishing regulations. One exception is in Wisconsin where regulation brochures encourage anglers to "cut-the-line" on deep-hooked fish. A campaign featuring a free hook inside an informational pamphlet was also distributed in Wisconsin (R. Hunt, Wisconsin Department of Natural Resources, personal communication). A similar incentive program was begun on Blackfoot Reservoir in southeastern Idaho in 1990. The success of these educational efforts is unknown.

Much can still be learned about bait-hooking mortality in streams. Field studies of hooking locations in actual stream fisheries with "real" anglers would provide better overall estimates. Most studies documenting hook locations have been conducted in hatcheries or in lakes or ponds. Those done in streams have limited sample sizes (Shetter and Allison 1955; Warner 1978).

Given the popularity of bait fishing, few studies have been done on ways to reduce hooking mortality (Lewensky 1986). Hook size can influence bait mortality (Shetter and Allison 1955; Hulbert and Engstrom-Heg 1980), but additional work is needed (Monguillo 1984). The potential of new hook designs in reducing the incidence of deep hooking should be investigated. The Circle C hook (Eagle Claw Tm) is one such possibility. The incidence of deep-hooking in ocean bottom fish with this hook type declines substantially when compared to traditional hook designs (S. Kaimmer, Pacific Halibut Commission, Seattle, personal communication). Finally, the effects of cutting the line should be examined in a wild fishery. Hooking mortality of wild trout may be higher than for hatchery fish (Monguillo 1984).

Continued growth in angler numbers will necessitate more restrictive regulations in the future. The continual displacement or elimination of **a** large segment of the angling public by bait restriction will meet resistance. This resistance may become more of an impediment to sound harvest restrictions. On many waters, imposing the minimum possible restrictions for a fishery while still providing good quality fishing will be the challenge of the future.

SUMMARY AND CONCLUSIONS

We compared the survival of deep-hooked hatchery trout released by cutting the leader and by removing the hook. Results show a 36% reduction in mortality when the line was cut. We observed no significant decline in condition of fish released with this method. Our results were similar to other work. All such work, however, has been done with hatchery fish. Existing information suggests that mortality can be substantially reduced if anglers cut leaders on deep-hooked trout. Results from these studies should, however, be verified with wild trout in natural streams before major public education efforts are undertaken.

RECOMMENDATIONS

1. Examine the effects that hook or fish size have on bait-hooking mortality. These factors could influence survival of fish released by cutting the leader.

2. Investigate alternative hook designs that might reduce the incidence of deep-hooking. The primary cause of high release mortality of bait-caught fish is the incidence of deep-hooking. Hook design may influence the frequency of hook "swallowing."

3. Verify results from these studies with wild trout in a stream. All past work on cutting leaders in salmonids, including this study, have been done with hatchery fish. Results from hatchery fish may not apply to wild trout.

4. Conduct a field study to describe the percentage of deep-hooking in "real" bait fisheries. This information would be useful in providing better estimates of overall bait-hooking mortality.

ACKNOWLEDGEMENTS

Numerous Idaho Fish and Game personnel participated in the study during the angler or biologist trials. Keith Johnson, Doug Munson, and Pat Saffel assisted with autopsies. Hagerman Hatchery personnel collected data on mortalities and reared the fish. Eight anglers volunteered for the study. Jon Dudley, Richard Scully, and Jack Van Deventer helped with analyses.

LITERATURE CITED

Bain, M.B. 1987. Structured decision making in fisheries management: Trout fishing regulations on the Au Sable River, Michigan. North American Journal of Fisheries Management. 7:475-481.

Burdick, B. and R. Wydoski. 1987. Effects of hooking mortality on a bluegill fishery in a western reservoir. Pages 187-196 in Proceedings of a National Sport Fishing Symposium on Catch-and-Release Fishing, Humboldt State University, Arcata, California.

Carline, R.F., T. Beard, Jr., and B.A. Hollender. 1990. Response of wild brown trout to elimination of stocking and no-harvest regulations without terminal tackle restrictions. Pennsylvania Cooperative Fish and Wildlife Research Unit, University Park.

Hulbert, P.J. and R. Engstrom-Heg. 1980. Hooking mortality of worm-caught hatchery brown trout. New York Fish and Game Journal. 27(1):1-10.

Hunsaker, II, D., L.F. Marnell, and F.P. Sharpe. 1970. Hooking mortality of Yellowstone cutthroat trout. Progressive Fish-Culturist. 32:231-235.

Klein, W.D. 1965. Mortality of rainbow trout caught on single and treble hooks and released. Progressive Fish-Culturist. 27:171-172.

Lagler, K.F. 1956. Freshwater fishery biology, 2nd edition. Wm. C. Brown Company Publishers, Dubuque, Iowa.

Lewynsky, V.A. 1986. Evaluation of special angling regulations in the Coeur d'Alene River trout fishery. Master's Thesis, University of Idaho, Moscow.

Mason, J.W. and R.L. Hunt. 1967. Mortality rates of deeply-hooked rainbow trout. Progressive Fish Culturist. 29:87-91.

Mongillo, P.E. 1984. A summary of salmonid hooking mortality. Washington Department of Game, Fisheries Management Division, Olympia.

Orciari, R.D. and G.H. Leonard. 1990. Catch-and-release management of a trout stream contaminated with PCB's. North American Journal of Fisheries Management. 10:315-329.

Peterman, R.M. 1990. Statistical power analysis can improve fisheries research and management. Canadian Journal of Fisheries and Aquatic Sciences. 47:2-15.

Shetter, D.S. and L.N. Allison. 1955. Comparison of mortality between fly-hooked and worm-hooked trout in Michigan streams. Michigan Department of Conservation Institute for Fisheries Research Miscellaneous Publication Number 9.

Shetter, D.S. and L.N. Allison. 1958. Mortality of trout caused by hooking with artificial lures in Michigan waters 1956-1957. Michigan Department of Conservation Institute for Fisheries Research Miscellaneous Publication Number 12.

Stringer, G.E. 1967. Comparative hooking mortality using three types of terminal gear on rainbow trout from Pennask Lake, British Columbia. Canadian Fish Culturist. 39:17-21.

Thurow, R. 1990. River and stream investigations: Wood River fisheries investigations. Idaho Department of Fish and Game, Job Completion Report, Project F-73-R-12, Boise.

Turner, S.E. 1986. The effects of restrictive fishing methods upon catch, harvest and survival of trout in Meramec River. Missouri Department of Conservation, Federal Aid in Fish Restoration, F-1-R-35, Study S-31, Jefferson City.

Warner, K. 1979. Mortality of landlocked Atlantic salmon hooked on four types of fishing gear at the hatchery. Progressive Fish-Culturist. 41(2):99-102.

Warner, K. and P.R. Johnson. 1978. Mortality of landlocked Atlantic salmon Salmo salar hooked on flies and worms in a river nursery area. Transactions of the American Fisheries Society. 107(6):772-775.

Weidlein, W.D. 1987. Mortality of released sublegal-sized smallmouth bass, catch-and-release implications. Pages 217-228 in Proceedings on a National Sport Fishing Symposium on Catch-and-Release Fishing, Humboldt State University, Arcata, California.

Westerman, F.A. 1932. Experiments show insignificant loss of hooked immature trout when they are returned to water. Michigan Department of Conservation Monthly Bulletin 2(12).

Wydoski, R.S. 1976. Relation of hooking mortality and sublethal hooking stress to quality fishery management. Pages 43-88 in Proceedings of a National Symposium on Catch and Release Fishing, Humboldt State University, Arcata, California.

Zar, J.H. 1974. Biostatistical Analysis. Prentice-Hall, Inc., Englewood Cliffs, New Jersey.

90REPRT

A P P E N D I C E S

Appendix A. Summary of tests of independent (Chi-square) from hooking mortality during the Hagerman bait-hooking study, June 22 to August 23, 1990.

Biologist Trial				Angler Trial			
Groups compared[a]	Calc. Chi-square	df	Prob.	Groups compared	Calc. Chi-square	df	Prob.
2,3,4	53.0	2	p <.001	1,2,3,4	224.0	3	p <.001
3,4	12.3	1	p <.001	2,3,4	133.3	2	p <.001
				3,4	22.3	1	p <.001

[a]Treatment groups identified as follows:
1 - Control
2 - Light-hooked
3 - Deep-hook removed
4 - Deep-cut-line

VTABS

Appendix B. Hook locations of both study survivors and mortalities originally released by cutting the line during the Hagerman bait-hooking study, June 22 to August 23, 1990.

Status	Organ hooked				Digestive tract			
	gills	pericaudal sac/heart	liver	total	esophagus	stomach	ascending intestine	total
Mortalities	4	3	13	20	1	2	0	3
Survivors	0	0	4	4	8	11	1	20

VTABS

JOB PERFORMANCE REPORT

State of: Idaho

Name: River and Stream Investigations

Project No.: F-73-R-13

Title: Electrophoresis Sampling Guidelines

Subproject No.: II

Job No.: 4

Study No.: IV

Period covered: March 1, 1990 to March 31, 1991

ABSTRACT

We reviewed literature and contacted several genetics experts to develop guidelines for electrophoretic sampling in Idaho. We conclude that electrophoresis should only be used to detect hatchery introgression. Highest priority should be given to suspected "pure" populations in waters or drainages currently receiving hatchery trout. Use of the technique for locating "unique" populations can be misleading and should not be used in our management decisions. Minimum levels of introgression that reduce performance of wild salmonid stocks are not available from the literature. Any introgression should be considered a threat to the productivity of our wild stocks.

Author:

Dan Schill
Senior Fishery Research Biologist

90REPRT

INTRODUCTION

Idaho Department of Fish and Game is concerned about the genetic integrity of our wild trout stocks (Idaho Department of Fish and Game Five-Year Management Plan 1991). This interest is an effort to preserve unique stocks and limit the effects of introgression. Hatchery introgression results in the progressive loss of genetic variation in wild trout populations (Allendorf and Leary 1988). Lost variation may lead to reduced performance of individual stocks in terms of growth, survival, fertility, and resilience to catastrophic events (Allendorf and Leary 1988). Genetic dilution can lead to a loss of the characteristics we think make wild trout stocks unique and to a loss of viability (Rieman and Apperson 1989). Rieman and Apperson (1989) recommended a survey of genetic purity of Idaho cutthroat stocks to 1) identify population strongholds, 2) provide a baseline for monitoring the genetic effects of hatchery programs, and 3) identify the best sites for collection of broodstock. A similar case can be made for wild rainbow trout stocks.

The Idaho Department of Fish and Game also receives frequent requests from other agencies and researchers for permits to conduct electrophoretic inventories. Some of these requests are designed to address introgression concerns. Others focus on the "uniqueness" of an individual population. We have few guidelines concerning electrophoretic studies and sample sizes needed for these different objectives. Since current genetic work requires lethal sampling, guidelines would be useful to fisheries personnel.

OBJECTIVE

1. To develop electrophoresis sampling guidelines for Idaho wild trout populations.

METHODS

Our approach to guideline development was a review of the literature and discussions with recognized genetics experts in several states. We sought to address to the following specific topics for guideline development:

1. Summarize the use of electrophoresis to distinguish subspecies or species of wild trout in Idaho.

2. Identify the level of introgression that can cause reduced levels of fitness or performance in wild trout.

3. Identify sample sizes needed to detect 1) harmful levels of introgression and, 2) genetic divergence at the subspecies level.

4. Identify questions relevant to our management goals that can be addressed with electrophoresis.

RESULTS AND DISCUSSION

Electrophoretic differentiation of fish stocks is based on alleles or alternate forms of genes. The frequency of occurrence for various alleles is often different among stocks of interest. When alleles can be used to differentiate between stocks, their location on the chromosome is called a diagnostic loci. A loci is considered diagnostic between stocks if stock A is fixed for a given allele 100% of the time and stock B has the alternative form 95% or more of the time (R. Leary, Montana State University, Missoula, personal communication). Diagnostic loci are available for differentiating between westslope cutthroat, Yellowstone cutthroat, and rainbow trout populations (Table 1). Yellowstone cutthroat trout cannot be clearly separated from Snake River fine-spotted cutthroat (Allendorf and Leary 1988) or from populations commonly referred to as Bonneville cutthroat trout from northern portions of their range (Williams, Boise State University, Boise, personal communication). Therefore, Bonneville cutthroat trout populations from southeast Idaho identified via meristic counts (Wallace 1978, 1980) probably cannot be separated from nearby Yellowstone stocks with electrophoresis. The above information can be used to evaluate the merits of proposed electrophoretic work. For example, recent requests by Caribou National Forest personnel to conduct a search of potential Bonneville cutthroat streams planted with Yellowstone cutthroat may have limited utility.

We found no guidelines on minimum levels of hatchery introgression expected to reduce fitness of wild stocks. Reduced fitness of hybrids (outbreeding depression) is thought to occur in some animals because the effects of locally adapted gene groups are disrupted via introgression (Allendorf and Leary 1988). Reduced developmental stability has been demonstrated for a number of salmonid hybrids (Leary et al. 1985). However, the same authors suggested that reduced developmental stability of some hybrids may not be great enough to result in large selective differences. The widespread existence of hybrid trout populations suggest that outbreeding depression is not a serious problem in trout (Allendorf and Leary 1988).

Several authors have reported reduced survival or growth of wild x hatchery progeny in streams (Reisenbickler and McIntyre 1977; Chilcote et al. 1986). In both of the above studies, however, introgression was probably severe. Quantifying the degree of introgression in the latter study is difficult because of the study design. Introgression in the Reisenbickler and McIntyre (1977) study was approximately 50% (J. McIntyre, United States Forest Service Intermountain Research Station, Boise, personal communication). No data on the comparative effects of various levels of introgression (e.g. 40%, 20%, 10%, 5%, and 1%) has been collected. Logistics and unrealistic time frames needed for such a study, perhaps 30 years, preclude such an effort (R. Leary, Montana State University, Missoula, personal communication). The conservative approach may conclude that any level of introgression with hatchery fish is detrimental to wild stocks. This is the approach taken with Idaho's wild salmon and steelhead streams (Idaho Department of Fish and Game 1991).

In addition to reduced fitness, Allendorf and Leary (1988) suggested that the eventual outcome of widespread introgression via hatchery rainbow trout could be the homogenization of all western trout stocks into a single "mongrel species." The loss of local native trout stocks could degrade the quality of fisheries for some persons and undo the result of thousands of years of evolution (Allendorf and Leary 1988).

As discussed above, minimum levels of hatchery introgression that could impact fitness have not been developed for wild fisheries. Therefore, the discussion of samples sizes needed to detect these levels is mute.

If we must assume any introgression is undesirable, what is the minimum sample size needed to detect any level at all? It has been suggested that levels below 1% introgression are difficult to detect (Allendorf and Leary 1988). Sample sizes needed to detect 1% foreign genes with 95% confidence for several Idaho stocks are as follows (R. Leary, Montana State University, Missoula, personal communication):

	N
Westslope cutthroat and rainbow trout	25
Westslope cutthroat and Yellowstone cutthroat	13
Yellowstone cutthroat and rainbow trout	15

The number of diagnostic loci available is the major factor influencing necessary sample size. Since individual labs may not all use the same diagnostic loci, sample sizes needed could vary. The above recommendations are based on diagnostic Loci identified by the Montana State Lab (Table 1). To calculate sample sizes needed for other labs (detecting 1% introgression with 95% confidence), obtain the number of diagnostic loci they intend to examine and use the following formula (R. Leary, Montana State University, Missoula, personal communication):

$$X = 149/(\text{number of diagnostic loci})$$

Only two loci have been identified for separating between Idaho wild rainbow trout and coastal rainbow trout (hatchery) stocks (Compton and Johnston 1985; Williams and Schiozawa 1991). Neither of these loci are diagnostic (R. Leary, Montana State University, Missoula, personal communication). Estimating the degree of hatchery rainbow introgression in our wild rainbow stocks is therefore more subjective (Williams and Schiozawa 1991). Unless diagnostic loci are found, attempts to document low levels of hatchery rainbow introgression in our wild rainbow trout stocks is not possible. Use of Mitochondrial DNA analyses in concert with electrophoresis may, in the future, provide better estimates (Williams, Boise State University, personal communication, Boise; R. Leary, Montana State University, Missoula, personal communication). Low levels of introgression could, however, remain undetected even with both techniques (R. Leary, Montana State University, personal communication).

Use of electrophoresis in detecting hatchery introgression in our wild stocks should receive more priority than in the past. Given the widespread planting of hatchery fish in Idaho streams, impacts to wild stocks may be a major problem. Genetic introgression is believed to be the most important cause for decline of westslope cutthroat trout in Montana (Liknes and Graham 1988). Detection of introgression and modification of hatchery plants could slow down or reverse losses.

We should prioritize future electrophoretic inventories by sampling populations thought to be suspected as "pure" (Rieman and Apperson 1989). Highest priority should be given to waters or drainages currently receiving hatchery trout. Low levels of hatchery rainbow introgression in wild rainbow trout stocks will not be detectable with current techniques. Such waters should receive less sampling priority than waters with other species combinations. Exceptions would be in situations where managers anticipate making major changes in stocking practices even if substantial introgression has already occurred.

Electrophoresis has also been used to document the "uniqueness" of a stock. For studies addressing genetic differences and "uniqueness" of wild stocks, it seems to be a consensus that the more loci screened the better. The number of loci screened should be at least 30 (Leary et al. 1987). The number of fish used is not well established and has ranged from 5 individuals per population to as many as 94 (T.C. Bjornn, University of Idaho, Moscow, personal communication). Reasonable guidelines for such work would be 30 fish and 45 loci (Williams, Boise State University, Boise, personal communication). In studies where funds are limited, increasing the number of loci examined is preferable to maximizing fish numbers. Increasing the number of fish simply increases the precision of allele frequency estimates. Increasing the number of loci examined allows more genetic material to be examined for differences (Williams, Boise State University, Boise, personal communication).

One philosophy that seems to accompany the search for "unique" genotypes is that those stocks should be afforded greater habitat protection than "normal" stocks. Electrophoretic techniques have important limitations, however. Results reflect specific genes in the DNA code. Any sample of specific loci reflect only a very small percentage of genes present (Ryman and Utters 1987). Statistical tests often used to compare allele frequencies also have poor statistical power (Kapuscinski and Jacobson 1987; Fairbarin and Roff 1980). Therefore, failure to find differences electrophoretically does not mean they are not present.

It seems likely that large numbers of populations with truly unique genetic characteristics will be incorrectly classified as not different using electrophoresis. Other genetic tools, such as Mitochondrial DNA analyses, may be more effective in tracing genetic lineages (Williams, Boise State University, Boise, personal communication). However, these techniques are not yet fully developed.

Until genetic tools examine most or all of the genome, the prudent approach to management would be to classify and manage stocks as "unique" based on phenotypic and behavioral characteristics. Such an approach has been strongly advocated in the past (Behnke 1979). Life history adaptations in many remote wild stocks may remain unknown for years into the future.

Use of electrophoresis for identifying unique stocks should not be a priority for our department. This does not mean to downplay the importance of academic workers documenting the genetic divergence of wild trout stocks.

However, given current shortages of funds for genetic work, it appears that our emphasis should be placed on the introgression question. This seems especially true when considering that we have direct control over hatchery introductions vs indirect control of habitat quality in most instances.

SUMMARY AND RECOMMENDATIONS

1. The Department should increase genetic inventory of important wild trout populations with emphasis on detecting introgression. Highest priority should be given to suspected "pure" populations in waters or drainages currently receiving hatchery trout. Less priority should be given to wild rainbow trout populations in waters being planted with hatchery rainbow trout.

2. Minimum sample sizes to detect 1% *introgression* (based on diagnostic loci identified by *Montana* State Lab) are as follows:

   - Westslope cutthroat and Yellowstone cutthroat trout (25)
   - Westslope cutthroat and rainbow trout (13)
   - Yellowstone cutthroat and rainbow trout (15)

   Sample sizes are dependent on the number of diagnostic loci compared and could, therefore, change for various labs.

3. Few loci exist to differentiate between coastal (hatchery) rainbow trout and our wild rainbow stocks. Electrophoretic results will be more subjective in these instances.

4. Electrophoretic results can be misleading since we can look at only a subsample of the entire genome. We should not use electrophoresis to classify wild populations as "unique." The best approach that the Department has taken is to advocate responsible habitat management for all wild trout populations.

5. If electrophoresis is used to detect "unique" populations, as many loci as possible should be screened (minimum of 45). Sample size should be 30 fish or more. Maximizing the number of loci examined is preferable to increasing the number of individual fish examined.

ACKNOWLEDGEMENTS

Ted Bjornn, Jack McIntyre, and Rob Leary all provided valuable input for this effort. A special thanks is due to Rick Williams who coached us through electrophoretic techniques in general and also provided specific input.

LITERATURE CITED

Allendorf, F.W. and R.F. Leary. 1988. Conservation and distribution of genetic variation in a polytypic species, the cutthroat trout. Conservation Biology. 2(2):170-182.

Behnke, R.J. 1979. Monograph of the native trouts of the genus Salmo of western North America. Unpublished Report.

Campton, D.E. and J.M. Johnson. 1985. Electrophoretic evidence for a genetic admixture of native and nonnative trout in the Yakima River, Washington. Transactions of the American Fisheries Society. 114:782-793.

Chilcote, M.W., S.A. Leider, and J.J. Loch. 1986. Differential reproductive success of hatchery and wild summer-run steelhead under natural conditions. Transactions of the American Fisheries Society. 115:726-735.

Fairbairn, D.J. and D.A. Roff. 1980. Testing genetic models of isozyme variability without breeding data: Can we depend on the ^{2}? Canadian Journal of Fisheries and Aquatic Sciences. 37:1149-1159.

Kapuscinski, A.R. and L.D. Jacobson. 1987. Genetic guidelines for fisheries management. Minnesota Sea Grant, University of Minnesota, Sea Grant Research Report Number 17, Duluth.

Leary, R.F., F.W. Allendorf, and K.L. Knudsen. 1985. Developmental instability and high meristic counts in interspecific hybrids of salmonid fishes. Evolution. 39(6):1318-1326.

Leary, R.F., F.W. Allendorf, and K.L. Knudsen. 1987. Differences in inbreeding coefficients do not explain the association between heterozygosity at allozyme loci and developmental stability in rainbow trout. Evolution. 41(6):1413-1415.

Likenes, G.A. and P.J.Graham. 1988. Westslope cutthroat trout in Montana: Life history, status, and management. American Fisheries Society Symposium 4.

Reisenbichler, R.R. and J.D. McIntyre. 1977. Genetic differences in growth and survival of juvenile hatchery and wild steelhead Salmo qairdneri. Journal of the Fisheries Research Board of Canada. 34:123-128.

Rieman, B.E. and K.A. Apperson. 1989. Westslope cutthroat trout synopsis and analysis of fishery information. Federal Aid in Fish Restoration, Idaho Department of Fish and Game, Project F-73-R-11, Boise.

Ryman, N. and F. Utter. 1987. Population genetics and fishery management. University of Washington Press, Seattle.

Wallace, R.L. 1978. Report of purity of Bonneville cutthroat trout Salmo Clarki Utah from upper Giraffe Creek, Bear River Drainage, Idaho. Department of Biological Sciences, University of Idaho, Moscow.

Wallace, R.L. 1980. Report of purity of Bonneville cutthroat trout, Salmo Clarki Utah from Preuss and Dry Creeks, Bear Lake County, Idaho. Department of Biological Sciences, University of Idaho, Moscow.

Williams, R.N., J.E. Carter, and D.K. Shiozawa. 1991. Genetic analysis of rainbow trout from the Big Wood River and Hayspur Hatchery, Blaine county, Idaho. Boise State University, BSU Evolutionary Genetics Lab Report 91-1, Boise.

Wishard, L.N., J.E. Seeb, F.M. Utter, and D. Stefan. 1984. A genetic investigation of suspected redband trout populations. Copeia. 1984:120-132.

Submitted by:

Daniel J. Schill
Senior Fishery Research Biologist

Approved by:

IDAHO DEPARTMENT OF FISH AND GAME

Jerry M. Conley, Director

Steven M. Huffaker, Chief
Bureau of Fisheries

Virgil K. Moore
Fishery Research Manager